[COMMITTEE PRINT]

SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION, AND OTHER LAUNCHING COUNTRIES: 1957–1986

REPORT

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FOR THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

TRANSMITTED TO THE

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*Ranking Republican Member.
**Resigned February 19, 1987 (H. Res. 89).
***Elected March 30, 1987 (H. Res. 133).

Letter of Transmittal

House of Representatives
Committee on Science, Space, and Technology
Washington, DC 20515

TO ALL MEMBERS, COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY:

I am pleased to transmit this updated Congressional Research Service report entitled, "Space Activities of the United States, Soviet Union and Other Launching Countries: 1957-1986." The report is based on careful analysis of information contained in numerous unclassified sources. It will be helpful to all readers interested in comparing the capability of the U.S. space program with the space programs of other nations.

This document is an excellent reference source and I am pleased to recommend it to you and your staff.

Sincerely,

ROBERT A. ROE
Chairman

Letter of Submittal

The Honorable Robert A. Roe
Chairman, Committee on Science, Space, and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am pleased to submit to you a report prepared by the Congressional Research Service entitled "Space Activities of the United States, Soviet Union, and Other Launching Countries: 1957-1986."

The report places into perspective the economic competition the United States faces from other nations in providing space services and hardware. Information contained herein provides useful statistical and programmatic summaries of the space activities of other launching nations.

Sincerely,

Bill Nelson

BILL NELSON, Chairman
Subcommittee on Space Science
and Applications

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LETTER OF SUBMITTAL

September 24, 1987

Honorable Bill Nelson
Chairman, Subcommittee on Space Science and Applications
Committee on Science, Space and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

We are happy to transmit to you this copy of the CRS report "Space Activities of the United States, Soviet Union and Other Launching Countries: 1957-1986" as you requested.

This annual report reviews space programs conducted by the United States, Soviet Union, China, Ind.., Japan and the European Space Agenc;--the "launching" countries. It was prepared by Ms. Marcia S. Smith, Specialist in Aerospace Policy in the Science Policy Research Division. We hope that it will assist you in your oversight of U.S. civilian space activities and how they compare with activities in other countries.

Sincerely,

Joseph E. Ross
Director

Enclosure

SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION AND OTHER LAUNCHING COUNTRIES: 1957-1986

Marcia S. Smith
Specialist in Aerospace Policy
Science Policy Research Division
February 27, 1987

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INTRODUCTION

During the first era of the space program, only the United States and the Soviet Union had the ability to place satellites in Earth orbit or send them off to distant planets. As early as 1965, this monopoly was challenged by France, but the launch vehicle it developed could only orbit very small payloads, and its use ended ten years later. Britain also developed its own launch vehicle, but it was used only twice. Both Britain and France later joined with nine other European countries to form the European Space Agency, which now has a launch vehicle called Ariane. Three other countries--China, India, and Japan--also have independent launch capabilities.

The purpose of this report is to summarize the programs of the United States, Soviet Union, and the other "launching" countries. Not included are efforts by private groups in the United States and abroad (such as OTRAG and Space Services, Inc.) that are attempting to develop their own orbital launch capabilities; if they succeed, these programs will be included in future editions of this report. A statistical summary of launches and payloads since the beginning of the space program in 1957 is shown in tables 1 and 2.

CRS has prepared several other reports on space activities which the reader may wish to consult for further information. A series of five-year studies on Soviet Space Programs has been prepared [for the Senate Aeronautical and Space Sciences Committee (now part of the Senate Commerce, Science, and Transportation Committee)] for various congressional committees since the early 1960s. The most recent edition, containing information through 1983, is available in three parts. United States Civilian Space Programs 1958-1978 (Volumes I and II) was written for and published by the House Science and Technology Committee in 1981 and 1983. World-Wide Space Activities, which provides detailed information on the space activities of all countries in the world except the United States and Soviet Union, was prepared for and published by the House Science and Technology Committee in 1977. CRS Report 84-127, Space Activities of the Non-Launching Countries updates information on countries which use space but do not have an indigenous launch capability. Several issues briefs are also available on specific space topics.

This report has been revised and updated by Marcia S. Smith, Specialist in Aerospace Policy in the Science Policy Research Division. Mr. Geoffrey Perry, M.B.E., head of the Kettering Group in England, provided some of the data for the tables and other information. The report is based on careful analysis of information contained in the numerous, unclassified sources cited in the above committee prints, and on earlier editions of this report written by the late Charles S. Sheldon II, formerly a Senior Specialist in Space and Transportation at CRS. Detailed citations are omitted for the purpose of keeping this annual update as brief as possible. The most frequently used sources, however, are publications of the Foreign Broadcast Information Service (FBIS), the Joint Publication Research

Service (JPRS) and trade publications such as Aviation Week and Space Technology and Aerospace Daily.

TABLE 1a. World-Wide Record of Successful Space Launches

YEAR	USSR	US	CHINA	JAPAN	ESA	INDIA	FRANCE*	AUST.*	UK*	TOTAL
1957	2									2
1958	1	5								6
1959	3	10								13
1960	3	16								19
1961	6	29								35
1962	20	52								72
1963	17	38								55
1964	30	57								87
1965	48	63					1			112
1966	44	73					1			118
1967	66	58					2	1		127
1968	74	45								119
1969	70	40								110
1970	81	29	1	1			2			114
1971	83	32	1	2			1		1	120
1972	74	31		1						106
1973	86	23								109
1974	81	24		1						106
1975	89	28	3	2			3			125
1976	99	26	2	1						128
1977	98	24		2						124
1978	88	32	1	3						124
1979	87	16		2	1					106
1980	89	13		2		1				105
1981	98	18	1	3	2	1				123
1982	101	18	1	1						121
1983	98	22	1	3	2	1				127
1984	97	22	3	3	4					129
1985	97	17	1	2	3					120
1986	91	6	2	2	2					103
Total	1,921	867	17	31	14	3	10	1	1	2,865

* Note that France, Australia and the United Kingdom no longer launch their own satelllites. France and the UK are members of the European Space Agency (ESA) which built the Ariane launch vehicle whose first launch was in 1979.

Italy conducted eight launches from 1967 to 1975 using U.S. Scout rockets from the San Marco platform off the coast of Kenya. Since the launch vehicles were American, NASA includes them in U.S. launch statistics and they are treated the same way here.

Prepared by CRS.

TABLE Ib. World-Wide Record of Known Space Launch Failures

YEAR	USSR	US	CHINA	JAPAN	ESA	INDIA	FRANCE	AUST.	UK	TOTAL
1957	*	1								1
1958	*	12								12
1959	*	10								10
1960	2	13								15
1961	*	12								12
1962	*	7								7
1963	*	8								8
1964	*	7								7
1965	*	7								7
1966	*	4		2						6
1967	*	3	*	1						4
1968	*	3	*		1**					4
1969	*	1	1	1	1**					4
1970	*	1	*	1	1**				1	4
1971	*	3	*		1**		1			5
1972	*	2	*							2
1973	*	2	*				1			3
1974	*	1	*							1
1975	2	3	*							5
1976	*		*	1						1
1977	*	2	*							2
1978	*	1	*							1
1979	*		1		1	1				3
1980	*	2	*							2
1981	2	1	*							3
1982	*		*		1					1
1983	1		*							1
1984	*		*							0
1985	1	1	*		1					3
1986	*	3	*		1					4
Total	8*	110	2*	6	8	1	2	-	1	138*

* It should be noted that both the Soviet Union and China rarely release information on failed launch attempts. In any launch vehicle development program failures can be expected, so it can be reasonably assumed that they have a similar success/failure ratio as the other launching nations.

** ESA, the European Space Agency, was formed in 1975 as the merger of the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO). The failures marked with a double asterisk under the ESA heading were part of ELDO's futile attempts to develop the Europa rocket. Those without asterisks are part of ESA's development of Ariane.

Prepared by CRS.

TABLE 1c. World-Wide Summary of Payloads Successfully Launched

YEAR	USSR	US#	CHINA	JAPAN	ESA	INDIA	FRANCE	AUST.	UK	TOTAL
1957	2									2
1958	1	5								6
1959	3	10								13
1960	3	17								20
1961	8	35								43
1962	26	59								85
1963	20	62								82
1964	39	73								112
1965	76	97					1			174
1966	52	101					1			154
1967	75	88					2	1		166
1968	85	64								149
1969	80	66					3			149
1970	103	40	1	1			1			146
1971	114	54	1	2					1	172
1972	109	42		1						152
1973	130	26								156
1974	114	28		1						143
1975	140	35	3	2			4			184
1976	141	34	2	1						178
1977	125	29		2						156
1978	142	41	1	3						187
1979	126	18		1	1					146
1980	132	16		1		1				150
1981	148	20	3	3	5	1				180
1982	141	20	1	1						163
1983	138	30	1	3	3	1				176
1984	138	34	2	3	6					183
1985	140	35	1	2	5					183
1986	132	11	2	3	4					152
Total	*2,683	1,190	18	30	24	3	12	1	1	3,962

* Historically, statistics for Soviet payloads have included the orbital platforms used to send payloads into highly elliptical or geostationary orbits, or into planetary trajectories. Devices used by other countries for similar purposes historically have not been counted as extra payloads. A total of 318 platforms are included in the Soviet count. At a later date, they will be subtracted to make the Soviet figures consistent with the other countries.

The space shuttle is counted as one payload, regardless of what it carries. Satellites deployed from the shuttle are counted as additional payloads if they are left in orbit. Italy's payloads launched from the San Marco Platform are counted in the U.S. total since they were launched with U.S. rockets.

Prepared by CRS.

TABLE 2. Summary of U.S. and Soviet Payloads by Mission*

CATEGORY	UNITED STATES		SOVIET UNION	
	1986	1957-1985	1986	1957-1985
Platforms	--	--	20	318
Earth Orbital Science	1	189	1	187
Unmanned Lunar/Planetary				
Moon		25		34
Mercury		1		0
Venus		8		33
Mars		9		16
Outer Planets		4		0
Interplanetary Space		8		0**
Applications				
Communications	2	212	13	168
Weather	2	85	1	60
Geodesy		19	1	25
Earth Resources		7	5	46
Materials Processing		0	1	1
Man-Related				
Earth Orbital Manned	1	43	1	94
Earth Orbital Man-Related		13	4	31
Lunar Manned		20		0
Lunar Man-Related		17		8
Launch Vehicle Tests		11	2	16
Gen. Engineering Tests		28		2
Reconnaissance				
Photographic		241	26	639
Elint (Electronic Intelligence)		83	8	94
Ocean Elint	3	21	4	49
Early Warning		42	6	47
Minor Military		43	1	143
Navigation		48	10	112
Tactical/Theater Comm.		0	28	352
Weapons-Related†				
FOBS		0		18
Antisatellite Targets		2		18
Antisatellite Interceptors		0		20
Other Military	2	0		0
Total	11	1,179	132	2,551

* Assignments are arbitrary to some extent and subject to revision each year as more information becomes available. This table is meant to provide only a general level of effort for each country and should be used cautiously.

** The Soviet VEGA probes which visited Venus and later Halley's Comet are included in the Venus total, rather than interplanetary probes.

† FOBS = Fractional Orbital Bombardment System; ASAT = Antisatellite.

Prepared by CRS.

SPACE ACTIVITIES IN 1986 AND PROSPECTUS FOR 1987

The total number of space launches in the world showed a decline in 1986, primarily because of the failure of three launch vehicles (the space shuttle, Titan, and Delta) in the United States and one (Ariane) in Europe. Although the Delta was back in operation by year's end, the Titan, space shuttle and Ariane remain grounded. The United States had only six successful launches in 1986, and Europe only two. The Soviet Union's launch rate was slightly lower in 1986 than the previous year, while Japan's and China's remained about the same. India had no launches.

In piloted space activities, 1986 saw tragedy for the United States with the death of the Challenger crew, but continued success for the Soviet Union with the launch of Mir, a third-generation space station. In space science, the United States achieved another first as Voyager 2 flew past Uranus, but U.S. space science suffered from NASA's inability to launch three major space science payloads following the shuttle accident. The Soviet Union, Europe and Japan all had probes that intercepted Halley's Comet.

In space applications, the French entered the remote sensing field with the successful launch of SPOT which ushered in a new age of media use of remote sensing images. The most notable was television coverage of the Chernobyl nuclear reactor accident in the Soviet Union where SPOT and U.S. Landsat images were used to show the damaged area.

Military space activities were relatively quiet in 1986, although two experiments for the Strategic Defense Initiative (SDI) program launched in the U.S. evoked some press coverage. The major concerns in the United States regarded the inability to launch heavy military payloads because of the Titan and space shuttle failures.

A. A TRAGIC YEAR FOR THE UNITED STATES

The year 1986 will go down in the records as the worst year for the U.S. space program since the beginning of the Space Age. Although it started with a successful shuttle launch on January 12, a crushing blow followed just two weeks later.

On January 28, the STS 51-L mission exploded 73 seconds after liftoff killing all aboard--Francis "Dick" Scobee, Michael Smith, Judith Resnik, Ellison Onizuka, Ronald McNair (all NASA astronauts), Gregory Jarvis (a payload specialist from Hughes Aircraft Co.), and S. Christa McAuliffe (the first "teacher in space"). President Reagan appointed a commission to investigate the so-called "Challenger accident," after the name of the space shuttle orbiter that was destroyed. Former Secretary of State William Rogers chaired the commission, which concluded that the accident was caused by a failure

in a joint in one of the two solid rocket boosters (SRBs) used to launch the orbiter.

The investigation of the accident and NASA had significant effects on the space program and resulted in a restructuring of NASA so that programs are managed more directly by headquarters rather than field centers. Although no one at NASA was directly blamed for the accident, by year's end new center directors had been named at Marshall Space Flight Center (responsible for the SRBs), Kennedy Space Center (the launch site), and Johnson Space Center (which had overall responsibility for the shuttle program). The head of the shuttle program at NASA headquarters was also replaced, although that change had been announced prior to the shuttle tragedy. The two men at Marshall with direct oversight of the SRB program were also replaced.

NASA's leadership was already in disarray prior to the accident, because of the indictment of NASA Administrator James Beggs for activities related to his past employment by General Dynamics. At the time of the tragedy, the agency was headed by an Acting Administrator, William Graham, a newcomer to the space business. He was later replaced by James Fletcher, who headed NASA from 1970-1976.

In addition to the human loss, the Nation lost its primary means of placing satellites into orbit when the Challenger exploded. The tragedy was followed by the explosion of a Titan launch vehicle during launch on April 18 and a similar fate awaited the launch of a Delta on May 3. This left only one major launch vehicle, the Atlas, in the U.S. stable, but since some its components were similar to those on Delta, it, too, was grounded. By the end of the year, the Delta and Atlas were back in service, but Titan and space shuttle were not. Titan launches are expected to resume in 1987; the first space shuttle flight is now scheduled for February 1988.

The launch vehicle failures wreaked havoc on all aspects of space activities. Government, commercial and foreign spacecraft had all been scheduled on the space shuttle. Government use of the Delta and Atlas was being phased out in lieu of the space shuttle, although private efforts to sell launches on these "expendable launch vehicles" or ELVs were proceeding, albeit slowly. (The Air Force had already decided not only to retain the Titan family, but to add a new member, the Complementary ELV or Titan IV, but it will not be available until the fall of 1988. DOD announced in 1986 that it will procure two new launches vehicles as well--a "Medium Launch Vehicle" which will be a modification of the Delta, and a "Heavy Lift Launch Vehicle" whose design has not been determined yet.) Most civilian and commercial spacecraft and many military satellites were due to be launched on shuttle. In the wake of the tragedy, NASA is reducing the frequency at which the shuttle can fly and the amount of payload that can be carried on one mission. Thus, even when the shuttle resumes service, there will be fewer flight opportunities. This affects the users who now have to wait their turn on shuttle or find alternative means to Earth orbit (complicated by the failure of the European Ariane launch vehicle, the shuttle's main competitor).

Particularly affected are those in the space science community. The year 1986 was to have been the "year of space science" with shuttle flights devoted to observations of Halley's comet, the launch of the Space Telescope, and two planetary launches (the U.S. Galileo

for studying Jupiter and the European Ulysses for investigating the Sun). These must now await the shuttle's return to service before they can be launched. Scientists who were planning to use Spacelab, the laboratory module that flies in the shuttle cargo bay, will also find many fewer opportunities once the shuttle resumes service.

From a policy perspective, the major change that resulted from the shuttle tragedy was a revised perception of the space shuttle system. NASA had designed the shuttle to be the single U.S. launch system. Although that attitude changed for DOD in the early 1980s with the decision to retain Titan, the shuttle was nevertheless supposed to be the primary U.S. launch system for the future. Now, the virtues of a "mixed fleet" encompassing both the shuttle and ELVs are being touted. Also, the Reagan Administration's strong focus on making the shuttle pay for itself through shuttle pricing policy decisions will undoubtedly disappear as the realities of a lower shuttle launch rate take effect. In addition, the Reagan Administration has decided that the shuttle cannot be used to launch commercial or foreign satellites unless they are "shuttle-unique," or designed specifically to be launched by the shuttle.

Many observers of the space program are arguing that a clearly enunciated goal for NASA and the civilian space program is a sine qua non of getting the agency back into business. In 1986, the National Commission on Space published its recommendations on the long term future of the space program in "Pioneering the Space Frontier." The Commission, created by Congress and appointed by the President, concluded that the United States should lead the way in opening the inner solar system for science, exploration and development over the next 50 years (the time frame of its study). In doing so, the Commission envisioned outposts and ultimately settlements on the Moon and Mars and establishment of a routine transportation system among the Earth, Moon and Mars.

What little good news there was concerning space activities in the United States in 1986 came from a previously launched space science probe, Voyager 2, which flew past Uranus. The pictures and data sent back astonished scientists. Of special note were views of the moon Mimas which in its small area exhibited a staggering variety of geological formations. Just as exciting was the discovery that Uranus may be surrounded by a superhot ocean of liquid water (that does not boil because of high atmospheric pressure). Earth is the only other body in the solar system that is known to have liquid water on its surface. Voyager 2 is now enroute to Neptune and will arrive in August 1989.

B. THE SOVIET UNION'S STEADY HAND

By contrast with the dismal year for the United States, the Soviet Union had another banner year in space. A new generation space station, called Mir (Peace), joined Salyut 7, the Soviet space station that has been in orbit since 1982. The one crew launched by the Soviets in 1986 (Soyuz T-15) went first to Mir, then "taxied" over to Salyut 7 for 50 days, then returned to Mir for another 19 days before returning home.

The major difference between Mir and its predecessors is that it has six docking ports which will permit a flexible research and

applications program to be conducted. Modules outfitted for specialized tasks, such as materials processing or earth resources, can be docked at the ports for varying lengths of time. When one set of equipment needs to be replaced, or when research directions shift from one area of inquiry to another, the modules can be changed to fit the research needs.

The Soviets also introduced another new version of the Soyuz used to carry crews back and forth to space. The latest, called Soyuz TM, replaces the Soyuz T series used since 1979. The major change apparently is related to the docking systems which are optimized for use with Mir. The Soviets have stated that they do not plan to send crews back to Salyut 7 and instead have boosted it to a high orbit (500 kilometers) and will monitor how its systems degrade over time.

The introduction of a new variant of Soyuz raises the issue of when a reusable space shuttle might become part of the Soviet fleet. The Pentagon continues to assert that the Soviets are developing both a shuttle the size of the U.S. shuttle, as well as a smaller "spaceplane." No orbital tests of the prototype spaceplane have taken place since 1984; no orbital tests of the full scale shuttle have occurred at all, although reports in the trade press state that the shuttle has been drop tested from an airplane in the same way that the U.S. shuttle was tested in 1977.

Another considerable Soviet success in 1986 was the encounter with Halley's Comet. Two Soviet Vega spacecraft reached the comet in March (along with one from Europe and two from Japan), and in a new show of openness, the Soviet Institute of Space Research hosted an international group of scientists to be on hand as the data arrived from the spacecraft.

Relative openness characterized the Soviet space program in other areas, too. For example, the Soviets announced the time of the Soyuz T-15 launch in advance. Later in the year, the Soviets announced that they would launch a crew including a Syrian cosmonaut and gave not only the date, but the time as well. Prior announcement of launch dates and times is quite uncharacteristic for the Soviets.

As part of their "Star Peace" initiative, the Soviets created a "civilian" space agency called Glavkosmos late in 1985 which began to take shape during 1986. The Soviets had been criticized in the West for having a space program run entirely by the military (the Strategic Rocket Forces). To counter the image of a military program, Glavkosmos was established to build and operate manned and unmanned spacecraft, although the actual launching of spacecraft apparently remains the responsibility of the military. Glavkosmos is now also responsible for negotiating international space agreements, a function previously performed by Interkosmos under the Soviet Academy of Sciences. Interkosmos will continue to work with the scientific community in the development of instruments, but the agreements will be negotiated through Glavkosmos.

Another Glavkosmos responsibility is marketing space services abroad. The Soviets apparently have realized the potential value of offering launch services, remote sensing data, and opportunities to conduct materials processing experiments in space. Although they have consummated only one commercial launch agreement (in 1982 with India

for a remote sensing satellite that will be launched in 1987), they have now increased their efforts to market services to other countries. They have stated that spacecraft being shipped to the Soviet Union for launch will be exempt from customs inspections and the spacecraft owner will be able to stay with the spacecraft through launch. These concessions on the part of the Soviets, who rarely have allowed outsiders at their launch facilities, may demonstrate the importance they attach to these activities. Although the United States has expressed concern about technology transfer (fearing the Soviets may dissect a satellite to learn about Western components and then reassemble it for launch), it may be that the primary Soviet interest in commercial arrangements is obtaining hard currency.

Two launches in 1986 may have been accomplished with a new Soviet launch vehicle, designated the SL-X-16 or the J vehicle in the West. The Soviets have not announced the introduction of a new launch vehicle into their fleet, but the Pentagon has reported for years that this vehicle, and a larger one with a capability similar to the U.S. Saturn V launch vehicle used to send the Apollo crews to the Moon, are in development.

C. CHINA, EUROPE, INDIA AND JAPAN

The European Space Agency (ESA) gained two new members in 1986, Austria and Norway (they had been associate members). ESA's launch vehicle Ariane, now operated by a company called Arianespace, completed two successful launches in 1986, but the vehicle failed in May and is not expected to resume service before the spring of 1987. ESA's Giotto spacecraft had a very successful encounter with Halley's Comet and was the only one of the five cometary probes to fly into the comet's nucleus. Scientists are still analyzing the data. The other major European scientific spacecraft that was to have been launched in 1986, Ulysses (for investigating the polar regions of the Sun), is in storage awaiting resumption of U.S. space shuttle flights. Negotiations continued with the United States over participating in the space station program, and ESA approved development of its own reusable manned vehicle, called Hermes.

On the national level, France entered the commercial remote sensing field with the launch of SPOT. The United States pioneered the development of land remote sensing satellites with the Landsat system beginning in 1972. Until the launch of SPOT, the United States held a monopoly on publicly available remote sensing data. SPOT has challenged this leadership, and policy disputes in the United States over the future of the Landsat system could lead to France playing the dominant role as a supplier of this data. SPOT can discern smaller objects than Landsat, but does not image the entire globe on each pass as does Landsat.

Britain established the British National Space Center with former ESA Director-General Roy Gibson as its head. Sweden's Viking satellite for studying auroras was launched, and Sweden continued plans to launch a small communications satellite on a Chinese rocket.

The Chinese launched their second communications satellite and what is probably another test of a reconnaissance capability, but their main achievement was promoting their Long March 3 rocket as a commercial vehicle. Although it has been launched only 3 times (twice

successfully), as U.S. and European launch vehicles have encountered difficulties, customers appear willing to take a risk with the Chinese. In December 1986, the Chinese formally inaugurated their Landsat receiving station, built under an agreement with the United States.

Japan successfully tested its new H-1 launch vehicle, and its two Halley's Comet probes, Sakigake and Suisei, successfully gathered data from the comet. Although they did not travel nearly as close to the comet as the Soviet or European probes, they did provide useful data to the International Halley's Watch team studying the comet.

India conducted no launches in 1986, and its next satellite, for remote sensing, is due to be launched by the Soviet Union.

D. PROSPECTUS FOR 1987

The United States is scheduled to conduct several launches in 1987, primarily for communications and weather. All will use ELVs, since the space shuttle is expected to resume service in February 1988 at the earliest. The Titan family of launch vehicles should be requalified for flight in 1987, providing at least some capability for DOD launches into polar orbit. Negotiations will continue with the international partners in the space station program. The policy issues likely to be addressed on a priority basis in 1987 are getting the shuttle safely back into service, and the future of the space station program. NASA is expected to launch new cost estimates for the station early in 1987 and they are likely to be significantly higher than predicted.

The Soviet Union announced at the October 1986 International Astronautical Federation meeting that they would send another crew to Mir early in 1987, and that a specialized module would dock with the station for x-ray astronomy. Tests launches of the new heavy lift launch vehicle are possible, although it is not as likely that one of them will carry the Soviet shuttle aloft.

Arianespace expects to resume launches of Ariane in the spring of 1987. As noted above, ESA's negotiations with NASA over the space station will also continue. Negotiations over the launch date for ESA's Ulysses mission may be contentious if the United States decides to postpone it past 1990. Japan is expected to launch its first remote sensing satellite, MOS, for studying the ocean. A scientific satellite, ASTRO-C, is also expected. China's launch plans are not known. India will have a remote sensing satellite launched for them by the Soviet Union. It is the first commercial launch conducted by the Soviets under the terms of an agreement signed in 1982 when the Soviets first attempted to sell launches abroad. To date, India is the only country to sign such an agreement.

PART ONE

U.S. AND U.S.S.R. SPACE ACTIVITIES

CHAPTER 1: EARLY HISTORY

In 1955 both the United States and the Soviet Union announced their intentions to launch small scientific satellites as a contribution to the International Geophysical Year; a world-wide scientific effort from July 1, 1957, to December 31, 1958, designed to increase understanding of the Earth and of space physics. President Eisenhower, wanting to demonstrate the U.S. commitment to using space for peaceful purposes, initiated Project Vanguard to develop a "civilian" rocket (i.e., not based on missile technology) and a satellite weighing 14 kilograms. He would not allow the Army to launch a satellite even though it had capability to do so in the fall of 1956.

Even though it was known that the Soviets were also working on rocket technology, the world was startled when they launched the first satellite, Sputnik 1 (weighing 84 kilograms), on October 4, 1957. Few had expected that the "backward" Soviet Union would beat the scientifically-advanced United States in this endeavor, and with a satellite many times heavier than what the United States was planning. Sputnik 2, launched on November 3, 1957, did not help the U.S. image: it weighed 508 kilograms, and carried a live dog, Layka. The first attempt to launch Vanguard, on December 6, 1957, ended in an embarrassing failure when it lifted three feet off the launch pad and came crashing back down in a fiery explosion. Eisenhower finally relented and allowed the Army to use its missile technology to place an Army satellite (Explorer 1) in orbit on January 31, 1958. Vanguard ultimately succeeded in placing a satellite in orbit on March 17, 1958. These early satellites were designed simply to prove the principles of spaceflight, although scientists were able to extract useful information, too. For example, the early Explorer satellites led to discovery of the Van Allen belts of radiation which encircle the Earth.

CHAPTER 2: MANNED SPACEFLIGHT

A. SHOOTING FOR THE MOON

1. Early Flights: 1961-1966

On April 12, 1961, Yuriy Gagarin became the first human to travel in space as he made one orbit of the Earth in Vostok 1. On May 5, Alan Shepard became the first American in space, although his Mercury-Redstone 3 (Freedom 7) flight was suborbital, lasting for only 15 minutes and landing about 480 kilometers downrange from Cape Canaveral.

Shepard's flight, even though it was suborbital, gave President Kennedy the confidence he needed to appear before Congress three weeks later, on May 25, 1961, to call upon the Nation to commit itself to the goal of landing a man on the Moon and returning him safely to Earth by the end of the decade. America accepted the challenge and the "Moon Race" was on, even though it was not until nine months later, on February 20, 1962, that John Glenn became the first U.S. astronaut to orbit the Earth.

The Soviet Vostok and U.S. Mercury flights were similar in purpose, and each country launched a total of six flights in their respective series. The flights demonstrated that humans could travel into space and return to Earth safely. The last of the Vostok flights took the first woman, Valentina Tereshkova, into space.

The Soviet Union followed its Vostok series with two flights of a modified version of that spacecraft, called Voskhod. On October 1964, Voskhod 1 carried the first three man crew, and in March 1965, the Voskhod 2 mission included the first extravehicular activity (EVA) or spacewalk. By contrast, the United States moved out quickly with the Gemini program in which 10 flights were conducted from 1965-1966 to increase the duration of the missions (up to 14 days), develop experience in rendezvous and docking procedures (skills which would be needed for the Apollo lunar landing program), and increase experience with EVAs (the first U.S. spacewalk occurred in June 1965). While the United States conducted the Gemini flights, no Soviet manned flights were made, and skepticism developed as to whether the two countries were in a race to the Moon or not. Since the Soviets conduct their space program secretively, it was difficult to determine their plans definitively. One clue, however, were statements by leaders in the Soviet space program, including cosmonauts. On July 11, 1966, cosmonaut Vladimir Komarov stated that "There is no need to make haste about a Moon trip by human beings--and the important thing is how to carry out everything in safety. But I can state positively that the

Soviet Union will not be beaten by the United States in a race for a human being to go to the Moon."

2. 1967: Double Tragedies

In 1967, both countries were ready to introduce new manned space vehicles --Apollo for the United States; Soyuz for the Soviet Union. The first flights of both of these vehicles ended in tragedy.

On January 27, 1967, the three man crew of what was to have been the first Apollo flight--Gus Grissom, Ed White, and Roger Chaffee--were killed when a fire erupted in their Apollo spacecraft during pre-launch tests. Three months later, on April 24, 1967, Vladimir Komarov, who had spoken so confidently of the Soviet Union being first on the Moon, was killed in the first Soyuz flight. In the final phase of recovery, the parachute lines became twisted, and he was killed upon impact with the Earth. Both manned programs were set back for a year as they responded to safety concerns raised by the separate accidents.

3. The United States Wins the Moon Race

When the manned programs resumed in October 1968, it was clear that the United States was ahead in the Moon race. The first U.S. flight (Apollo 7) was a full scale test of the Apollo command module in Earth orbit. The first Soviet flight (Soyuz 2 and 3) was a simple rendezvous between a manned and an unmanned spacecraft, something that had been accomplished repeatedly in the U.S. Gemini program. In December 1968, three U.S. astronauts--Frank Borman, Jim Lovell, and Bill Anders--spent Christmas in lunar orbit. Their flight had been made possible by development of a special launch vehicle, the Saturn V, which was used to launch all the Apollo lunar missions. The Soviet Union was reported to be developing a launch vehicle with equivalent thrust, but the vehicle never achieved orbit (there are rumors that three test launches resulted in spectacular explosions), and as of the end of 1986, the Soviets still had not launched a vehicle with a capability similar to the Saturn V.

On July 20, 1969, the United States officially won the Moon Race when Neil Armstrong and "Buzz" Aldrin became the first humans to set foot on the lunar surface, while Mike Collins orbited overhead. Through 1972, five more U.S. crews set foot on the lunar surface (Apollo 12, 14, 15, 16 and 17) returning 380 kilograms of lunar material to Earth for analysis. A sixth attempt, Apollo 13 in 1970, narrowly averted tragedy when the crew safely returned to Earth after an explosion in the service module.

Meanwhile, the Soviet Union continued a few unmanned flights to develop hardware for a manned lunar mission (Zond 4-8 from 1968 to 1970, and apparently four Kosmos flights in 1970-1971), but lacking a launch vehicle with sufficient capability, they were unable to send people to the Moon and still have not done so, although they have retrieved lunar samples with automated probes.

Instead, they turned their attention to Earth orbit. In January 1969 they accomplished the first docking of two manned ships (Soyuz 4 and 5) permitting crew transfer using EVA. Soyuz 6, 7, and 8 in October 1969 made a group coorbital flight, although it is thought

that two of the ships (Soyuz 7 and 8) were supposed to dock, but were unable to do so. In 1970, Soyuz 9 set what was then a duration record of 18 days. From that point, the Soviets began their very successful space station program described below.

B. DETENTE IN SPACE: THE APOLLO-SOYUZ TEST PROJECT (ASTP)

As a contribution toward detente, and as a spur to the development of a universal, androgynous docking system which would allow each country to rescue the other's astronauts, the United States and Soviet Union agreed to work cooperatively to conduct a joint flight, called the Apollo-Soyuz Test Project (ASTP), in which a three-man Apollo crew docked with a two-man Soyuz crew in 1975.

The Soviet Union agreed to a few modifications of the Soyuz spacecraft to permit this docking, and a test flight (Soyuz 16) was conducted in 1974. Both countries launched their ASTP spacecraft on July 15, 1975; the Soviet flight was designated Soyuz 19, while the U.S. flight has always been referred to simply as ASTP. The two ships docked on July 17, and undocked on July 19 after two days of exchange visits and joint experiments. Soyuz 19 returned to Earth on July 21; ASTP landed on July 24. Since ASTP was the last flight for the Apollo spacecraft, the androgenous docking adaptor became obsolete at the end of the mission.

C. SPACE STATIONS

1. Soviet Space Stations

a. The First Generation: Salyut 1-5

The world's first space station, Salyut 1, was placed in orbit by the Soviet Union on April 19, 1971. When docked with a Soyuz, it had about 100 cubic meters of interior space, compared to 275 cubic meters in the American Skylab space station (without the Apollo spacecraft).

The first attempt to occupy the space station failed when the Soyuz 10 crew was unable to enter the station after successfully docking with it. The Soviets then launched the three-man Soyuz 11 crew which was able to enter the station and became the first space station crew. They spent 24 days conducting medical, Earth resources, and astronomical experiments. Tragically, the crew was killed during their return to Earth on June 29, 1971. They had improperly closed a valve between two sections of the Soyuz spacecraft, and when the sections separated during reentry, the spacecraft's atmosphere vented into space. The Soviets had long since given up the practice of requiring crews to wear spacesuits because of confidence in their hardware, so the three men-- Georgiy Dobrovolskiy, Vladislav Volkov and Viktor Patsayev--were asphyxiated. Since this flight, all Soviet cosmonauts have been required to wear spacesuits during launch and reentry, and because the original Soyuz was unable to accommodate three space-suited crew members, the Soviets launched only two-man crews for the next ten years until the redesigned Soyuz T came into use.

The next two space station launches, Salyut 2 and Kosmos 557 in 1973, were failures. They were followed by two free-flying Soyuz missions (Soyuz 12, a diagnostic flight following the Soyuz 11 tragedy, and Soyuz 13, a manned astronomical observatory).

Finally, in June 1974, the Soviets successfully orbited the next space station, Salyut 3. Western observers immediately noticed some interesting differences from Salyut 1: the crews sent to the station were all military instead of mixed military and civilian, when the crew entered the space station they switched to military telemetry, the orbit was lower (perhaps to improve picture resolution), and after it was unoccupied for a month, a data capsule was separated and returned to Earth in a manner similar to the return of photographic reconnaissance film. Therefore, this is counted in the West as the first military space station, optimized for reconnaissance activities. The Soviets stated that it was for Earth resources investigations. Of the two crews sent to Salyut 3, only one (Soyuz 14) was able to dock with it.

Salyut 4, launched December 26, 1974, was similar to Salyut 1 and so is considered a civilian mission by western analysts. Two crews docked with it (Soyuz 17 for 30 days and Soyuz 18 for 63 days), although a third (called the April 5th Anomaly or Soyuz 18A) was supposed to dock. In that case, a problem in the launch vehicle resulted in an abort which brought the crew back to Earth (unharmed) before reaching orbit. In November 1975, the unmanned Soyuz 20 docked with the station for a 90-day powered down test of the Soyuz spacecraft (although biological specimens were carried for scientific experiments).

The next station, Salyut 5, was similar to Salyut 3, suggesting the Soviets had an alternating program of military and civilian space stations during this period. Two crews successfully occupied Salyut 5 (Soyuz 21 for 46 days, Soyuz 24 for 18 days), while a third (Soyuz 23) was unable to dock.

Between the first two missions to Salyut 5, the Soviets launched another free-flying mission, Soyuz 22, which tested an East German-built multispectral camera (the MKF-6) for Earth resources studies. A modified version of the camera (MKF-6M) was installed on Salyut 6 and 7.

b. The Second Generation: Salyut 6 and 7

On September 29, 1977, the Soviets launched a second-generation space station called Salyut 6. The most important improvement in the station was the addition of a second docking port at the aft end of the station which enabled resupply flights to dock with the station while a crew was on board. Flights of a new unmanned cargo ship, called Progress, began in 1978, and the first in-space fuel transfer took place between Progress 1 and Salyut 6 in January of that year. Progress is a modified Soyuz spacecraft and not designed to survive reentry (thus it can take supplies to a space station, but cannot bring anything back to Earth). The second port was also used for docking additional crews to occupy the station as visitors to the long-duration crew. This provided opportunities for taking supplies to the orbiting crew, and for bringing the results of the various

experiments conducted on board back to Earth (which would otherwise have to wait until the main crew returned).

During its four and a half years in orbit, Salyut 6 hosted 16 crews (2 other manned missions were unable to dock) which conducted a wide variety of Earth resources, materials processing, biomedical, and biological experiments (such as plant growth). The station was occupied for approximately 50 percent of the time it was in orbit.

During the Salyut 6 period, the Soviets increased the duration for a crew in space to 185 days (the longest U.S. spaceflight is 84 days). The long duration crews would be visited by other crews who would remain for a week. Among the visiting crews were the first "international cosmonauts" representing the countries that belong to Interkosmos, the organization through which the Soviets cooperate with their allies. Cosmonauts from Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Romania, and Vietnam all visited Salyut 6. A Bulgarian was launched, but was not able to dock because the Soyuz 33 ferry craft malfunctioned. The Soviets have announced that they will launch a Bulgarian in 1988 to the new Mir space station. None of the other Interkosmos countries appear to have been given a second opportunity.

A total of 12 Progress flights resupplied the crews, and three other unmanned missions (Soyuz 34, Soyuz T, and Kosmos 1267) docked with the station. Soyuz 34 was launched to replace the aging Soyuz 32 for returning the crew to Earth after the Soyuz 33 failure. Soyuz T was an unmanned test of a new version of Soyuz with upgraded avionics and other changes. The Soyuz T replaced the original Soyuz in 1981 and was used until it was replaced by another modified version, Soyuz TM, in 1986. Kosmos 1267 docked with Salyut 6 in June 1981. The Soviets announced that its purpose was testing a modular space station concept, and that Kosmos 1267 had life support systems on-board. Later, "Aviation Week and Space Technology" reported that Kosmos 1267 was in fact a "battle station" in orbit, armed with infrared homing devices. Salyut 6 and Kosmos 1267 were deorbited on July 29, 1982 while they were still docked. The full nature of Kosmos 1267's mission remains unclear, but probably was a modular space station test as the Soviets claimed.

Salyut 7 was launched on April 19, 1982, the eleventh anniversary of the launch of Salyut 1. The space station is virtually identical to Salyut 6, although the Soviets report that it has an improved navigation system. It was last occupied in 1986, and the Soviets have stated that they do not intend to reactivate Salyut 7 since the new Mir space station is available. Salyut 7 is now in a high orbit (500 kilometers) in a mothballed condition, and the Soviets plan to monitor the station to see how its systems deteriorate over time.

Salyut 7 hosted 10 crews and was resupplied by 13 Progress missions. During the Salyut 7 era, a new record of 237 days was set by a three-man crew in 1984. Although the Soviets assert that they have determined no reasons why spaceflights cannot be extended for longer periods of time, they have not done so. Among the visiting crews to Salyut 7 were a Frenchman, an Indian, and a Soviet woman, Svetlana Savitskaya, who made two flights, the first woman to do so. On the second flight, she also became the first woman to make a spacewalk.

Two modules, Kosmos 1443 and Kosmos 1686, based on the Kosmos 1267 design were docked with Salyut 7 (Kosmos 1686 is still attached). The Soviets refer to these as multipurpose vehicles that can be used as cargo ships (with 2.5 times the capacity of Progress), space tugs, and/or modules to increase the habitable volume of the space station by 50 cubic meters. Kosmos 1443 also had a descent module for returning material to Earth, although Kosmos 1686 does not.

During the Salyut 7 period, the Soviets had to overcome many difficulties with the space station itself, and nearly suffered another tragedy in 1983 when a launch vehicle about to send a crew into orbit caught fire. Using the emergency abort tower on top of the launch vehicle, the module containing the crew was propelled away from the launch pad and landed safely 3 kilometers away.

The hardware problems with the space station led the Soviets to begin using EVA routinely during the Salyut 7 era. It was only in 1983 that a single crew performed two EVAs on one mission. Their purpose was to attach new solar panels to the main space station arrays to provide additional power and compensate for degradation of the original panels. Subsequent crews added more solar panels, one set of which were made of gallium arsenide, the first time this substance had been used for space solar panels to date. The 1983 experience gave the Soviets confidence in repeated spacewalks by a single crew, and in 1984 a crew made six EVAs, five of which were needed to replace a fuel valve.

In 1985, the space station required another round of major repairs after it lost electrical power during a period that it was unoccupied. The station was essentially in a deep-freeze condition when the Soyuz T-13 repair crew arrived. Communications and radar systems were not functioning, complicating rendezvous and docking operations. The two-man crew reactivated the station and later became part of the first crew transfer. The three-man Soyuz T-14 crew was sent to Salyut 7, and for one week all five men shared the space station. Then, one member of the Soyuz T-13 crew and one from Soyuz T-14 returned to Earth, leaving one member of the Soyuz T-13 crew and two from Soyuz T-14 aboard. Such crew transfers had been expected for years, since they are required for permanently occupied facilities (individuals would not remain on the space station for years at time; instead they would be replaced probably on a three or four month schedule).

The Soyuz T-14 crew also represented another space first; it was the first space mission aborted because of a medical emergency (at least, the Soviets have not openly stated that any other missions were terminated prematurely for such a reason). The commander of the mission, Vladimir Vasyutin, developed an "inflammation" which could not be cured with medical supplies aboard the space station and the crew had to return in haste. The Soviets have not provided further details about Vasyutin's affliction. The Soyuz T-15 crew, after first spending time on the new Mir space station in 1986 (see below), spent 50 days aboard Salyut 7 closing out activities.

c. Third Generation: MIR ("PEACE")

On February 20, 1986, the Soviets launched a third generation space station called Mir, the Russian word for peace. That the space

station carries this name is not surprising since in 1985 the Soviets placed a proposal called "Star Peace" before the United Nations to counter President Reagan's "Star Wars" program. They have continued to slowly open their space program, a crack at a time, and have created a new "civilian" space agency called Glavkosmos (discussed in chapter 6) to promote the image of a space program devoted to peaceful purposes. Calling their new space station Mir, rather than Salyut 8, is clearly part of this effort.

Mir is about the same size as the earlier Soviet space stations (they are all launched by the same vehicle), but has several significant differences. First, it has six docking ports rather than two. Second, it has two very long solar panels instead of the three shorter panels used since Salyut 3. Third, most the scientific equipment that normally is installed inside the space station will be carried instead on separate modules that will dock at one of the ports, leaving a greater volume of space available in the station itself for the crew. This has enabled, for example, the provision of private sleeping quarters for two crew members. More quarters may be included on the modules sent to dock with Mir. This is in response to complaints by previous crews about the lack of privacy. The Soviets have also made a point of stating that Mir has more and better computers to operate the station, relieving the crew of many routine tasks. Communications between Mir and ground control can be routed through a relay satellite, permitting greater communication times with the crews.

There are two axial docking ports (one at each end), and four ports around the circumference of one end of the station. Modules docking at one of the side ports will dock first with the forward axial port and then be "swung around" using a type of remote manipulator system that will be carried on the module. The additional ports give the Soviets a more flexible system, permitting them to carry out several different research activities in specialized modules that can be docked with the station part of the time and in free flight (away from human interference) on other occasions.

Only one crew, Soyuz T-15, docked with Mir in 1986; two Progress missions brought supplies. After spending 51 days on Mir, the crew used their Soyuz spacecraft to taxi over to Salyut 7 where they spent another 50 days closing out activities. They also tested a flexible structure, extending it and then collapsing it again. The exercise is related to building large space structures in the future. They then taxied back to Mir and stayed for another 19 days. Their total amount of time in space, including travelling between the space stations, was 125 days. Mir has been unoccupied since July 16, 1986; the next crew is expected to be launched early in 1987.

2. U.S. Space Stations

a. Skylab

On May 14, 1973, the United States orbited a space station developed from a Saturn IV-B stage called Skylab. The space station suffered considerable damage when its micrometeoroid shield and one of the main solar panels were ripped off during launch, but the first

crew to visit the station effected repairs, and ultimately three crews docked with Skylab, for 28, 59, and 84 days respectively. A wide range of experiments were conducted in solar observations, Earth resources observations, biomedical research, and materials processing. The last crew left the space station in February 1974, and in July 1979 the station reentered the Earth's atmosphere, raining debris over parts of Western Australia and the Indian Ocean.

b. The U.S./International Space Station

In his January 1984 State of the Union address, President Reagan called on NASA to build a permanently occupied space station within a decade. NASA is now embarked on a program with the European Space Agency, Japan and Canada to build such a station, but how much of it will be available by 1994 remains in question.

The space station program has been affected by the 1986 Challenger disaster (see below) in several ways. First, the rules for operating the shuttle have changed. There will be fewer shuttle flights per year (16 instead of 24 according to current NASA expectations), and the mass that can be launched on each shuttle mission will be lower. Since the space station components are to be launched via the shuttle, this will increase the amount of time needed to get the station operational. Second, the amount of science and applications experiments that can be conducted on the shuttle has been sharply cut back, especially for those activities that require the use of Spacelab, the scientific laboratory that fits inside the shuttle cargo bay. These experiments were to provide experience for scientific activities on the space station. Third, although NASA has been provided with funding to procure a replacement orbiter, funding is still required for fixing the shuttle's solid rocket boosters. Thus, NASA's already difficult choices of where to spend its relatively limited funding resources will be that much harder.

Nevertheless, the space station program is proceeding. Following the Challenger tragedy, NASA reviewed its space station plans and reaffirmed the basic design--a "double keel" space station with two habitable modules provided by the United States, another by the European Space Agency, and a fourth by Japan. This occupied part of the station is to be in an orbit inclined 28.5 degrees to the equator, allowing a due-East launch from Cape Canaveral. In addition, there will be an automated platform in the same orbit as the occupied portion of the station, plus another one in "polar" orbit circling Earth's poles.

NASA expects that the space station and associated platforms will be used for a wide range of scientific and commercial space projects, including astronomical observatories, remote sensing activities, and manufacturing of very pure pharmaceuticals and crystals. The Department of Defense maintained for several years that it had no mission requirements for a space station, but in December 1986 announced that it would want to use the station and expressed concern about the agreements NASA was negotiating with its international partners about use of the station for peaceful purposes. At the end of 1986, the international space station negotiations were on hold because of DOD's announcement.

3. Future Space Stations

While there is considerable discussion in the media and among aerospace professionals about the potential for space colonies, there are no firm plans for such an endeavor at this time. A popular scenario calls for construction of a 10,000 person colony at a Lagrange point where the gravitational forces of the Earth and Moon cancel each other out. This is often called the L-5 proposal, denoting one of the five Lagrange coordinates in the Earth-Moon system.

Broader proposals for future space stations were made in the 1986 report of the National Commission on Space (see chapter 7). The Commission recommended creation of a space infrastructure to support opening the inner solar system for science, exploration, and development over the next 50 years. In doing so, space stations (or spaceports as the Commission calls them) would be established in Earth, Moon and Mars orbits, and at the L1 Lagrange point. In addition, the Commission's "cycling spaceships" for transportation to Mars would be similar in design to the spaceports. All would have the ability to produce artificial gravity to compensate for the deleterious effects of weightlessness on the human body over long periods of time. The spaceports would be transfer points in the transportation system rather than colonies; the Commission felt that space colonies such as those proposed by the L5 supporters were beyond the 50 year time frame of its report.

A November 28, 1983, article in Pravda outlined long term Soviet space station goals. The article, authored by President of the Ukrainian Academy of Sciences B. Paton and Soviet Doctor of Technical Sciences Y. Semenov, described a complex of installations in altitudes ranging from 200 to 4,000 kilometers linked to Earth by freight and passenger transport spacecraft. The complex would have specialized modules for scientific research, living quarters, power generation, refueling, repair workshops, and construction sites for producing and installing standardized construction components. No time frame was given for when such a complex might begin to be established.

D. REUSABLE SPACE VEHICLES

1. The U.S. Space Shuttle

In 1972, President Nixon approved development of a reusable manned spacecraft, called the space shuttle. The shuttle consists of a reusable orbiter about the size of a DC-9 which carries the crew and payloads, the external tank which holds the fuel for the three liquid hydrogen-liquid oxygen engines (called the main engines) for the orbiter, and two solid rocket boosters (SRBs) attached to either side to provide additional power during the first two and a half minutes of launch. The external tank breaks up in pieces as it reenters over the Indian Ocean; the SRBs are recovered from the Atlantic Ocean for refurbishment and reuse. Four flight-worthy orbiters have been built: Colombia, Challenger, Discovery, and Atlantis. A fifth orbiter, Enterprise, was used for tests in the late 1970s, but was not designed to be flown in space. It is now on display by the Smithsonian Institution near Dulles Airport in Virginia.

After making 24 successful flights, the shuttle program suffered a tremendous tragedy when the 25th mission, STS 51-L, exploded 73 seconds after liftoff on January 28, 1986 at Cape Canaveral, Florida. The orbiter Challenger was destroyed and all seven crew members were killed--NASA astronauts Francis "Dick" Scobee, Michael Smith, Judith Resnik, Ronald McNair, and Ellison Onizuka and payload specialists Gregory Jarvis (an engineer with Hughes Aircraft Inc.) and S. Christa McAuliffe (a schoolteacher). The failure of a joint in one of the SRBs has been blamed for the accident.

The investigation of the Challenger tragedy was performed by a commission established by President Reagan, called the Rogers Commission after its chairman former Secretary of State William Rogers. Although the Commission did not affix blame to any individuals, the public record made clear that employees at NASA and Morton Thiokol, which manufactures the SRBs, should have chosen not to launch that day. The weather was unusually cold at Cape Canaveral and temperatures had dipped below freezing during the night. Test data has suggested that the seals (called O rings) around the SRB joints lost much of their effectiveness in very cold weather. A Thiokol engineer at the launch site had recommended against launch, but was overruled by his superiors at the company's Utah headquarters. NASA's Marshall Space Flight Center was responsible for the SRB program within the agency, and officials there approved the launch as well.

The aftermath of the Challenger tragedy has called into question NASA management practices, past decisions about the design of the SRBs, and the health of the U.S. civilian space program. To a large extent, this tragedy has overshadowed the successes that the shuttle program enjoyed prior to January 28, 1986.

The first space shuttle flight was successfully accomplished on April 12, 1981, and was followed by three more orbital test flights (one in 1981, two in 1982). The first "operational" launch of the shuttle took place on November 11, 1982, and was used to launch two communications satellites into geostationary orbit.

Four shuttle missions were launched in 1983, including missions that included the first U.S. woman in space (Sally Ride) and the first black American (Guion Bluford), and the first flight of the European-built Spacelab, which flies in the cargo bay of the orbiter. The Spacelab 1 mission included the first non-American to fly on an American manned mission (a West German). Five shuttle missions were successfully accomplished in 1984, and included the first use of the Manned Maneuvering Unit which allows an astronaut to travel away from the shuttle without being tethered to it. On later flights that year, three satellites were retrieved by astronauts, one of which (the Solar Maximum Mission) was repaired and redeployed in orbit, while the other two (Westar and Palapa) were returned to Earth for repair and eventual relaunch. Kathryn Sullivan became the first American woman to perform a spacewalk, Sally Ride became the first American woman to fly into space twice, and procedures for in-space refueling were demonstrated.

In 1985, nine shuttle flights were successfully accomplished, including the first dedicated mission for DOD. This mission garnered considerable attention from the media, which was unaccustomed to the

lack of information about launch schedules and payloads involved in a DOD launch. The media portrayed this an example of the "militarization" of NASA, but it may be viewed as a continuation of past policy as all U.S. launch vehicles are used by both military and civilian customers.

During 1985, shuttle crew size increased to eight, and one of the crews included U.S. Senator Jake Garn. The utility of the shuttle for repairing satellites was demonstrated again with the repair of the Leasat communications satellites which had failed to function after deployment on an earlier shuttle flight. Two Spacelab missions were flown, including one with animals, the first time humans and animals have flown together in space. Another crew tested space construction techniques. One of the 1985 missions encountered the first serious problem during launch when one of the three main engines ceased functioning during ascent. The crew safely reached orbit, although it was not at the altitude intended.

There was one successful shuttle launch in January 1986 which included U.S. Congressman Bill Nelson among the crew. The next flight was the ill-fated STS 51-L. The shuttle program is now scheduled to resume service in February 1988 although NASA has emphatically emphasized that they will not fly again until that are certain that it is safe to so, and there is nothing "magic" about the February 1988 timing.

2. Aerospace Plane

For the longer term future, the United States is conducting research and development on several new propulsion technologies and materials through the National Aerospace Plane (NASP) program. The concept is not new, but it is believed that the technologies are finally becoming available to achieve a marriage between air-breathing and rocket technologies. Ultimately, NASP could replace the space shuttle and other launch vehicles for taking people and some cargo into orbit. It could also serve as an aircraft, taking people around the world in a few hours. It is in this application that President Reagan referred to it as the "Orient Express" in his 1986 State of the Union address.

The goal of the NASP program is to develop a reusable vehicle that will significantly lower the cost of placing material in orbit, as well as serve as an aircraft which can travel around the world in very short amounts of time. Theoretically, it could be launched from many different sites around the world, just like conventional aircraft. Unlike other space launch vehicles, the aerospace plane would be launched horizontally.

The NASP program is funded primarily through the Air Force, although the Navy and the Strategic Defense Initiative Organization are interested in its applications, and the program is managed by the Defense Advanced Research Projects Agency (DARPA) which conducts cross-agency research. NASA is also providing some of the funding. The near-term goal of the program is to develop an "X" plane (in the mold of the X-1 or X-15) in the 1992-1993 time frame to test whatever materials and technologies have been developed through the research program at that time. Aerospace plane technologies are so advanced

that it is not known yet whether or not the plane can work, much less what it will cost if it enters operation.

3. Soviet Development of a Spaceplane and Shuttle

Speculation has existed for many years that the Soviet Union is developing a reusable space shuttle vehicle. During the late 1970s, there were unconfirmed reports that drop tests of a shuttle vehicle had been made from aircraft and that a space launch could be expected soon.

An operational launch of a full-scale shuttle has not yet taken place, although since 1982, four tests have been made of a sub-scale prototype spaceplane. All were launched from the small Kapustin Yar launch facility, and all landed in the water (the first two in the Indian Ocean, the last two in the Black Sea). Each has made only one and a quarter orbits of the Earth. The four spacecraft and their launch dates are: Kosmos 1374, June 3, 1982; Kosmos 1445, March 15, 1983; Kosmos 1517, December 27, 1983; and Kosmos 1614, December 19, 1984. No more tests have taken place since Kosmos 1614.

It is expected that the spaceplane would accommodate a crew of perhaps two. What the Soviets would use it for is unknown, although it might be used as a ferry craft to take crews to a space station, a ferry craft between space stations, or to fly military sortie missions.

The DOD also asserts that the Soviets are developing a space shuttle the same size as that of the United States. "Aviation Week and Space Technology" has reported that drop tests of the shuttle from an aircraft have been made, and that the shuttle carries air-breathing engines. The U.S. shuttle does not have air-breathing engines, which is why it must land on its first attempt--presumably the Soviet shuttle could make a fly-around if it developed difficulty in landing the first time. Recent editions of the Pentagon's "Soviet Military Power" have included artists' sketches of the Soviet shuttle, showing it carried on the back of a Bison bomber (the way the U.S. orbiters are transported across country on a 747) or being launched. It is assumed in the West that the Soviets need their heavy lift launch vehicle in development (see chapter 6) to launch the shuttle, so orbital flights may not take place for some time.

TABLE 3a. Summary List of Manned Space Flights

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1961							
Apr. 12	Vostok 1	Gagarin	4,725	1:48	same	1	1:48
May 5	MR-3	Shepard	1,290	:15	same	—	:15
July 21	MR-4	Grissom	1,286	:16	same	—	:31
Aug. 6	Vostok 2	G. Titov	4,731	25:18	same	17	27:06
1962							
Feb. 20	MA-6	Glenn	1,355	4:55	same	3	5:26
May 24	MA-7	Carpenter	1,349	4:56	same	3	10:22
Aug. 11	Vostok 3	Nikolayev	4,722	94:22	same	64	121:28
Aug. 12	Vostok 4	Popovich	4,728	70:57	same	48	192:25
Oct. 3	MA-8	Schirra	1,373	9:13	same	6	19:35
1963							
May 15	MA-9	Cooper	1,376	34:20	same	23	53:55
June 14	Vostok 5	Bykovskiy	4,720	119:06	same	81	311:31
June 16	Vostok 6	Tereshkova	4,713	70:50	same	48	382:21
1964							
Oct. 12	Voskhod 1	Komarov Yegorov Feoktistov	5,320	24:17	same	16	455:12
1965							
Mar. 18	Voskhod 2	Belyayev Leonov	5,682	26:02	same	17	507:16
Mar. 23	Gemini 3	Grissom (2) Young	3,225	4:53	same	3	63:41
June 3	Gemini 4	McDivitt White	3,574	97:56	same	66	259:33
Aug. 21	Gemini 5	Cooper (2) Conrad	3,605	190:55	same	128	641:23
Dec. 4	Gemini 6	Borman Lovell	3,663	330:55	same	220	1,302:33
Dec. 15	Gemini 7	Schirra (2) Stafford	3,546	25:51	same	17	1,354:15
1966							
Mar. 16	Gemini 8	Armstrong Scott	3,788	10:41	same	7	1,375:37
June 3	Gemini 9	Stafford (2) Cernan	3,750	72:21	same	47	1,520:19
July 18	Gemini 10	Young (2) Collins	3,741	70:47	same	46	1,661:53
Sept. 12	Gemini 11	Conrad (2) Gordon	3,860	71:17	same	47	1,804:27
Nov. 11	Gemini 12	Lovell (2) Aldrin	3,763	94:35	same	63	1,993:37
1967							
Jan. 27	AS-204	Grissom (3)† White (2)† Chaffee†	20,412	[Not a space flight, but date of fatal fire on pad during test preliminary to later scheduled flight.]			
Apr. 23	Soyuz 1	Komarov (2)†	6,450	26:48	same	18	534:04

† Fatality

TABLE 3a. Summary List of Manned Space Flights--continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1968							
Oct. 11	Apollo 7	Schirra (3) Eisele Cunningham	20,569	260:09	same	174	2,774:04
Oct. 26	Soyuz 3	Beregovoy	6,575	94:51	same	64	628:55
Dec. 21	Apollo 8	Borman (2) Lovell (3) Anders	43,663	147:01	same	2(Earth) 10(Moon)	3,215:07
1969							
Jan. 14	Soyuz 4	Shatalov (Yeliseyev) (Khrunov)	6,625	71:21	same	48	795:54
Jan. 15	Soyuz 5	Volynov Yeliseyev Khrunov	6,585	72:54	same for 1* 47:49 for 2*	49	868:48
Mar. 3	Apollo 9	McDivitt (2) Scott (2) Schweickart	43,185	241:01	same	162	3,938:10
May 18	Apollo 10	Stafford (3) Young (3) Cernan (2)	48,638	192:03	same	2(Earth) 31(Moon)	4,514:19
July 16	Apollo 11	Armstrong (2) Collins (2) Aldrin (2)	49,698	195:19	same	2(Earth) 30(Moon)	5,100:16
Oct. 11	Soyuz 6	Shonin Kubasov	6,577	118:43	same	80	1,106:14
Oct. 12	Soyuz 7	Filipchenko Gorbatko V. Volkov	6,570	118:40	same	80	1,462:14
Oct. 13	Soyuz 8	Shatalov (2) Yeliseyev (2)	6,646	118:51	same	80	1,699:56
Nov. 14	Apollo 12	Conrad (3) Gordon (2) Bean	49,804	244:36	same	2(Earth) 45(Moon)	5,834:04
1970							
Apr. 11	Apollo 13	Lovell (4) Haise Swigert	49,990	142:55	same	2(Earth) 1(Moon)	6,262:49
June 1	Soyuz 9	Nikolayev (2) Sevastyanov	6,500	424:59	same	286	2,549:54

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1971							
Jan. 31	Apollo 14	Shepard (2) Roosa Mitchell	46,347	216:02	same	2(Earth) 34(Moon)	6,910:55
Apr. 19	Salyut 1	(Occupied by Soyuz 11 crew)	18,600?	---		---	---
Apr. 22	Soyuz 10	Shatalov (3) Yeliseyev (3) Rukavishnikov	6,575?	47:46	same	32	2,693:12
June 6	Soyuz 11	Dobrovolskiy† V. Volkov (2)† Patsayev†	6,575?	570:22	same	385	4,404:18
July 26	Apollo 15	Scott (3) Irwin Worden	52,759	295:12	same	2(Earth) 74(Moon)	7,796:31
1972							
Apr. 16	Apollo 16	Young (4) Duke	51,571	265:51	same	2(Earth) 65(Moon)	8,594:04
Dec. 7	Apollo 17	Cernan (3) Schmitt Evans	51,808	301:52	same	3(Earth) 75(Moon)	9,499:40
1973							
May 14	Skylab 1	(Occupied by Skylab 2, 3 & 4 crews)	89,439	---		---	---
May 25	Skylab 2	Conrad (4) Kerwin Weitz	30,803	672:50	same	433	11,518:10
July 28	Skylab 3	Bean (2) Garriott Lousma	30,694	1,427:09	same	919	15,799:37
Sept. 27	Soyuz 12	Lazarev Makarov	6,575?	47:16	same	32	4,498:50
Nov. 16	Skylab 4	Carr Gibson Pogue	31,232	2,017:16	same	1,298	21,851:25
Dec. 18	Soyuz 13	Klimuk Lebedev	6,575?	188:56	same	127	4,876:42
1974							
June 24	Salyut 3	(Occupied by Soyuz 14 crew)	18,900?	---		---	---
July 3	Soyuz 14	Popovich (2) Artyukhin	6,570?	337:30	same	252	5,631:42
Aug. 26	Soyuz 15	Sarafanov Demin					
Dec. 2	Soyuz 16	Filipchenko (2)	6,570?	48:12	same	32	5,728:06
		Rukavishnikov (2)	6,570?	142:24	same	96	6,012:54
Dec. 26	Salyut 4	(Occupied by Soyuz 17, 18 crews)	18,900	---		---	---

† Fatality

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1975							
Jan. 10	Soyuz 17	Gubarev Grechko	6,570?	709:20	same	466	7,431:34
Apr. 5	Anomaly	Lazarev (2) Makarov (2)	6,570?	:20	same	—	7,432:14
May 24	Soyuz 18	Klimuk (2) Sevastyanov (2)	6,570?	1,511:20	same	993	10,454:54
July 15	Soyuz 19	Leonov (2) Kubasov (2)	6,800	142:31	same	96	10,739:56
July 15	ASTP	Stafford (4) Slayton Brand	14,743	217:28	same	145	22,503:49
1976							
June 22	Salyut 5	(Occupied by Soyuz 21, 24 crews)	18,900?	—		—	—
July 6	Soyuz 21	Volynov (2) Zholobov	6,570?	1,182:23	same	790	13,104:42
Sept. 15	Soyuz 22	Bykovskiy (2) Aksenov	6,570?	189:52	same	127	13,484:26
Oct. 14	Soyuz 23	Zudov Rozhdestvenskiy	6,570?	48:07	same	32	13,580:40
1977							
Feb. 7	Soyuz 24	Gorbatko (2) Glazkov	6,570?	425:26	same	285	14,431:32
Sept. 29	Salyut 6	(Occupied by Soyuz 26, 27, 28, 29, 30, 31, 32, 35,36, 37, 38, T2, T3, T4, 39, 40 crews)	18,900?	—		—	—
Oct. 9	Soyuz 25	Kovalenok Ryumin	6,570?	48:45	same	32	14,592:02
Dec. 10	Soyuz 26	Romanenko Grechko (2)	6,570?	898:06	2,314:00	590	19,157:02
1978							
Jan. 10	Soyuz 27	Dzhanibekov Makarov (3)	6,570?	1,558:53	142:59	1,024	19,443:00
Mar. 2	Soyuz 28	Gubarev (2) Remek (Czechoslovakia)	6,570?	190:16	same	125	19,832:32
June 15	Soyuz 29	Kovalenok (2) Ivanchenkov	6,570?	1,911:23	3,350:48	125	26,525:08
June 27	Soyuz 30	Klimuk (3) Hermaszewski (Poland)	6,570?	190:13	same	125	26,905:14
Aug. 26	Soyuz 31	Bykovskiy (3) Jahn (German Dem. Rep.)	6,570?	1,628:14	188:49	1,070	27,282:52

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1979							
Feb. 25	Soyuz 32	Lyakhov Ryumin (2) (Returned unmanned)	6,570?	2,596:24	4,200:36	1,711	35,684:04
Apr. 10	Soyuz 33	Rukavishnikov (3) Ivanov (Bulgaria)	6,570?	47:01	same	31	35,778:06
June 6	Soyuz 34	(Launched unmanned, returned Soyuz 32 crew)	6,570?	1,770:17	0	1,153	——
1980							
Apr. 9	Soyuz 35	Popov Ryumin (3)	6,570?	1,321:29	4,436:12	868	44,650:30
May 26	Soyuz 36	Kubasov (3) Farkas (Hungary)	6,570?	1,580:54	188:46	1,040	45,028:02
June 5	Soyuz T-2	Malyshev Aksenov (2)	7,000?	94:19	same	62	45,216:40
July 23	Soyuz 37	Gorbatko (3) Pham Tuan (Viet Nam)	6,570?	1,911:17	188:42	1,257	45,594:04
Sept. 18	Soyuz 38	Romanenko (2) Tamayo Mendez (Cuba)	6,570?	188:43	same	124	45,971:30
Nov. 27	Soyuz T-3	Kizim Makarov (4) Strekalov	7,000?	307:08	same	204	46,892:54
1981							
Mar. 12	Soyuz T-4	Kovalenok (3) Savinykh	7,000?	1,794:38	same	1,196	50,482:10
Mar. 22	Soyuz 39	Dzhanibekov (2) Gurragcha (Mongolia)	6,570?	188:43	same	125	50,859:26
Apr. 12	STS 1	Young (5) Crippen	98,658	54:21	same	36	22,612:31
May 14	Soyuz 40	Popov (2) Prunariu (Romania)	6,570?	188:41	same	126	51,236:58
Nov. 12	STS 2	Engle Truly	103,811	54:13	same	36	22,720:57
1982							
Mar. 22	STS 3	Lousma (2) Fullerton	106,000	192:05	same	128	23,105:07
Apr. 19	Salyut 7	(Occupied by Soyuz T-5, T-6, T-7, T-9, T-10 T-11, T-12, T-13, T-14 and T-15 crews)	18,900?	——		——	——
May 13	Soyuz T-5	Berezovoy Lebedev (2)	7,000?	2,549:06	5,073:05	1,690	61,383:08

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1982 (cont.)							
June 24	Soyuz T-6	Dzhanibekov (3) Ivanchenkov (2) Chretien (France)	7,000?	189:51	same	126	61,952:41
June 27	STS-4	Mattingly (2) Hartsfield	108,797	169:10	same	112	23,443:27
Aug. 19	Soyuz T-7	Popov (3) Serebrov Savitskaya	7,000?	2,712:51	189:52	1,800	62,522:17
Nov. 11	STS-5	Brand (2) Overmyer Allen Lenoir	111,201	122:14	same	82	23,932:23
1983							
Apr. 4	STS-6	Weitz (2) Bobko Musgrave Peterson	114,201	120:24	same	80	24,413:59
Apr. 20	Soyuz T-8	V. Titov Strekalov (2) Serebrov (2)	7,000?	48:18	same	32	62,667:11
June 18	STS-7	Crippen (2) Hauck Ride Fabian Thagard	110,013	146:24	same	98	25,145:59
June 27	Soyuz T-9	Lyakhov (2) Aleksandrov	7,000?	3,585:46	same	2,391	69,838:43
Aug. 30	STS-8	Truly (2) Brandenstein Thornton Bluford D. Gardner	104,675	145:09	same	97	25,871:44
Sept. 26	(Soyuz T-10)	V. Titov (—) Strekalov (—)	(Not a spaceflight. Crew jettisoned using emergency abort system after fire erupted in launch vehicle prior to launch)				
Nov. 28	STS-9	Young (6) Shaw Parker Garriott (2) **Lichtenberg** **Merbold** **(W. Germany)**	110,031	247:47	same	165	27,358:26
1984							
Feb. 3	STS 41-B	Brand (3) R. Gibson McCandless McNair Stewart	113,508	191:16	same	127	28,314:46

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1984 (cont.)							
Feb. 8	Soyuz T-10	Kizim (2) Solovyev Atkov	7,000?	1,510:43	5,686:50	1,008	74,370:52
Apr. 3	Soyuz T-11	Malyshev (2) Strekalov (3) Sharma (India)	7,000?	4,365:48	189:41	2,914	87,468:16
Apr. 6	STS 41-C	Crippen (3) Scobee Hart van Hoften G. Nelson	115,342	167:40	same	112	29,153:06
July 17	Soyuz T-12	Dzhanibekov (4) Savitskaya (2) Volk	7,000?	283:14	same	189	88,317:58
Aug. 30	STS 41-D	Hartsfield (2) Coats Resnik Hawley Mullane **C. Walker**	119,491	144:57	same	97	30,022:48
Oct. 5	STS 41-G	Crippen (4) McBride Ride (2) Sullivan Leestma ~~Scully-Power~~ ~~Garneau~~ **(Canada)**	110,119	197:24	same	132	31,404:36
Nov. 8	STS 51-A	Hauck (2) D. Walker Allen (2) A. Fisher D. Gardner (2)	119,421	191:45	same	128	32,363:21
1985							
Jan. 24	STS 51-C	Mattingly (3) Shriver Onizuka Buchli **Payton**	N/A	73:33	same	49	32,731:06
Apr. 12	STS 51-D	Bobko (2) Williams Hoffman Griggs Seddon **C. Walker (2)** **Garn**	113,802	167:55	same	112	33,906:31

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1985 (cont.)							
Apr. 29	STS 51-B	Overmyer (2) Gregory Thornton (2) Thagard (2) Lind **van den Berg** **Wang**	111,982	168:09	same	112	35,083:34
June 6	Soyuz T-13	Dzhanibekov (5) Savinykh (2)	7,000?	2,691:12	2,691:12** 4,035:51**	1,794	91,222:23
June 17	STS 51-G	Brandenstein (2) Creighton Lucid Nagel Fabian (2) **Baudry (France)** **Sultan Salman Al-Saud (Saudi Arabia)**	116,310	169:40	same	113	36,271:14
July 29	STS 51-F	Fullerton (2) Bridges Henize England Musgrave (2) **Bartoe** **Acton**	114,590	190:46	same	127	37,606:36
Aug. 27	STS 51-I	Engle (2) Covey Lounge W. Fisher van Hoften (2)	118,981	170:18	same	114	38,458:06
Sept. 17	Soyuz T-14	Vasyutin Grechko (3) A. Volkov	7,000?	1,557:52	1,557:52** 213:13**	1,039	98,373:58
Oct. 3	STS 51-J	Bobko (3) Grabe Hilmers Stewart (2) **Pailes**	N/A	97:45	same	65	38,946:51
Oct. 30	STS 61-A	Hartsfield (3) Nagel Buchli (2) Bluford (2) Dunbar **Ockels (ESA)** **Furrer (FRG)** **Messerschmid (FRG)**	110,568	168:44	same	112	40,296:45
Nov. 26	STS 61-B	Shaw (2) O'Connor Spring Cleave Ross **C. Walker (3)** **Neri (Mexico)**	118,664	165:05	same	110	41,452:18

TABLE 3a. Summary List of Manned Space Flights—continued

Launch Date	Vehicle Name	Crew (no. of flights)	Weight (kgs)	Ship Duration (hr:min)	Crew Duration (hr:min)	Orbits	National Cumulative Personhours
1986							
Jan. 12	STS 61-C	R. Gibson (2) Bolden Hawley (2) G. Nelson (2) Chang-Diaz **Cenker** **B. Nelson**	116,120	143:04	same	95	42,453:46
Jan. 28	STS 51-L	Scobee (2)† Smith† Resnik (2)† Onizuka (2)† McNair† **Jarvis†** **McAuliffe†**	121,939		Exploded 73 seconds after liftoff. All aboard were killed.		
Feb. 20	Mir	(Occupied by Soyuz T-15 crew)					
Mar. 13	Soyuz T-15	Kizim (3) Solovyev (2)	7,000?	3,000:01	same	2,000	104,374:00

*Soyuz 4 was launched carrying only Shatalov. Soyuz 5 carried Volynov, Yeliseyev and Khrunov. The latter two transferred to Soyuz 4 via a spacewalk and returned to Earth with Shatalov.

**Soyuz T-13 and T-14 involved the first space station crew transfer. Dzhanibekov returned to Earth on his Soyuz T-13 spacecraft with Grechko who was launched in Soyuz T-14. Savinykh, who was launched on Soyuz T-13, remained on the space station with Vasyutin and Volkov who were launched on Soyuz T-14.

Names in bold are payload specialists, rather than career NASA astronauts.

Prepared by CRS.

† Fatality

TABLE 3b. Number of Individuals Who Have Flown in Space

COUNTRY	TOTAL INDIVIDUALS WHO HAVE FLOWN IN SPACE
United States	120
Soviet Union	60
Bulgaria*	1
Canada†	1
Czechoslovakia*	1
Cuba*	1
France*†	2
German Democratic Republic*	1
Germany, Federal Republic of†	3
Hungary*	1
India*	1
Mexico†	1
Mongolia*	1
Netherlands†	1
Poland*	1
Romania*	1
Saudi Arabia†	1
Vietnam*	1
TOTAL.....	199

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*Flew on Soviet spaceflight.

†Flew on U.S. spaceflight.

Prepared by CRS.

CHAPTER 3: SPACE APPLICATION FLIGHTS

Applications satellites are those spacecraft whose functions provide direct applications to a user community, including communications, navigation, remote sensing of the Earth's surface, weather, and geodesy. While the term is usually applied to civilian satellites, they are close cousins of military satellites, and in most cases it is extremely difficult to distinguish whether a particular satellite should be counted as military or civilian. Military space activities in general are discussed in chapter 5.

A. COMMUNICATIONS

The United States was the first country to experiment with communications satellites. At first, satellites which could store information for later relay to Earth (sometimes referred to as store/dump) were used (such as Score) and at about the same time, passive balloon reflectors (Echo, for example) were launched. Beginning in 1963, the United States started placing communications satellites in geostationary orbit at 35,880 kilometers altitude above the Equator. A satellite in this orbit will maintain a fixed position relative to a point on the ground. Color TV, telephone calls, and data can be relayed across oceans. As capacity has grown, the costs of operation have diminished. Commercial and government satellites are regularly launched to serve both the military and civilian sectors. The United States has also begun launching Tracking and Data Relay Satellites (TDRSS) for relaying communications between spacecraft and ground control. One satellite is in orbit; the second was lost on the STS 51-L mission in 1986. Two TDRSS satellites are slated for early launches once the space shuttle resumes service.

At the initiative of the United States, the International Telecommunications Satellite Organization (INTELSAT) was established in 1964 to provide for an international communication satellite system. By the end of 1986, 112 countries were members of INTELSAT. The success of INTELSAT spawned creation of the International Maritime Satellite Organization (INMARSAT) in 1979 for maritime communications and it now has 46 members. The Soviet Union does not belong to INTELSAT (although it uses the system), but is a member of INMARSAT.

The Soviet Union established the first domestic communications satellite system beginning in 1965. It has a different approach to communications satellites, deploying its Molniya satellites in highly elliptical orbits with an apogee of approximately 40,000 kilometers over the northern hemisphere and a perigee of approximately 500 kilometers over the southern hemisphere, rather than in geostationary

orbit. This provides a long linger time over the northern hemisphere (8 hours), and a small system of these satellites can provide 24 hour coverage. The Molniya type of orbit is better than geosynchronous orbit for communicating at high latitudes where the curvature of the Earth makes it difficult for signals to reach from the Equator.

Although the Molniya orbit is good for internal communications in the Soviet Union, geostationary satellites are useful for international communications. In 1974, the Soviets placed their first geostationary satellite in orbit. Since then, they have developed three different geostationary satellite systems: Raduga (1975), Ekran (1976), and Gorizont (1978). Two geostationary satellites with experimental systems were launched in 1982: Gorizont 5, which in addition to its regular transponders in the 6/4 GHz band, carried new Luch transponders which operate in the 14/11 GHz range, and Volna transponders for maritime use; and Kosmos 1366 which the Soviets reported was performing tests in the super-high frequency range. A satellite which may be similar to Kosmos 1366 was launched in 1984 (Kosmos 1546). The Soviets have also filed a notice with the International Telecommunication Union for a satellite system called GALS which is thought to be for military communications, although none of this series has been launched yet. The Soviets have also begun using geostationary satellites for data relay, and noted in 1986 that Kosmos 1700 was being used to relay communications between the Mir space station and ground control.

Instead of joining INTELSAT, the Soviet Union formed INTERSPUTNIK in 1971 as a competitor. At the end of 1986, 14 countries were members of INTERSPUTNIK.

The Soviets have retained the old store/dump type of communications satellite for tactical and theater operations.

B. METEOROLOGICAL SATELLITES

The United States has an operational weather satellite system using two satellites in Sun-synchronous polar orbits (called NOAA for the National Oceanic and Atmospheric Administration which operates them), and two Geostationary Operational Environmental Satellites (GOES) in geostationary orbit. (Each time a satellite in a Sun-synchronous orbit passes over any given location on Earth, it is precisely the same time as when it last passed over that site, e.g. 9:30 a.m., thus providing data with the same Sun angles which makes analysis of the data much easier.) NASA developed a low-cost ground terminal for receiving data from the polar orbiting satellites, called APT (automatic picture transmission) equipment, which is available through a variety of companies to anyone in the world. The U.S. Department of Defense has its own polar orbiting weather satellites, called the Defense Meteorological Satellite Program (DMSP).

The Soviet Union has polar orbiting weather satellites called Meteor, but these are not in Sun-synchronous orbits (they use the Sun-synchronous orbits for the Meteor-Priroda remote sensing flights, however). The Soviets do not have geostationary weather satellites, although they had promised to launch such a satellite as part of an

international weather program in 1979. Their current plans for the program, called GOMS, are unknown.

C. NAVIGATION

The United States has a navigation satellite system operated by the U.S. Navy. Originally called Transit, it was renamed the Navy Navigation Satellite System and provides two-dimensional data (latitude and longitude). While not particularly suited to commercial economics, it is highly effective for naval purposes. Commercial ships have been permitted to use the system since 1967 if they care to invest in the necessary computer equipment.

An even more ambitious global positioning system, called NAVSTAR, entered the testing phase in 1978 with four satellites. Ultimately the system will have 18 satellites (plus three on-orbit spares) and will provide three-dimensional data (latitude, longitude, and altitude), world-wide, 24 hours a day. The NAVSTAR system is expected to be fully operational in 1990.

The Soviet Union claims to have had an operational navigation satellite system for many years, but did not identify the first satellite in the series, Kosmos 1000, until 1978. A model of the satellite at the Paris Air Show had the label "Tsikada," but no satellite has had that designation at the time of launch. All the satellites which appear to serve a navigation function in the Soviet program are designated under the broad Kosmos label. Analysis by the Kettering Group has shown that there are separate satellites for civilian and military users. The Soviet system is thought to be similar to Transit.

The Soviets are launching a three-dimensional navigation satellite system like NAVSTAR, too. Their system is called "GLONASS," and the satellites are launched three at a time. Twenty-four GLONASS satellites had been launched by the end of 1986, but these are thought to be part of a developmental program. It is not known when the system will be operational.

D. GEODESY AND MAPPING

The United States has flown many geodetic flights in the interest of tying together maps of different parts of the world and for basic scientific studies to understand better the true shape of the planet. (Such data are needed for many purposes, including missile targeting.) If there have been mapping flights as well, the results have not been published.

The Soviet Union professes an interest in both geodesy and mapping, but too few findings have been made available to judge how far along they are in comparison with the United States. Some flights in the Kosmos series have orbital characteristics which would support such missions.

E. EARTH RESOURCES

Remote sensing satellites are designed to look down at the Earth from space to search for mineral deposits, oil fields, forest fires, pollution sources, and diseased trees and agricultural crops. Using remote sensing data, crop inventories can be made, snowfall and water status reported, and fisheries run more efficiently. Since 1972, the United States has launched 5 Landsat satellites for remote sensing purposes. At this time, the Government has decided not to launch any more satellites, but hopes that the private sector will take over that role. Legislation passed Congress in 1984 (P.L. 98-365) to facilitate transfer of the remote sensing program to the private sector. The Department of Commerce (which has operational responsibility for the Landsat series) selected a contractor, EOSAT, to commercialize the system, but it has been complicated by the Executive Branch's reluctance to provide promised subsidies to EOSAT. At the end of 1986, EOSAT was beginning to lay off employees because Congress and the Administration had not agreed upon the details of the plan to transfer Landsat completely to EOSAT. The future of the program continues to be in doubt.

The Soviet Union has developed a great interest in remote sensing. Crews on board Salyut space stations spend a considerable amount of time performing Earth resources investigations with a variety of cameras, including a six channel multispectral camera developed by East Germany. There also have been two flights of Meteor-Priroda satellites which were placed in Sun-synchronous orbits. A third series of remote sensing flights is launched under the Kosmos designation, and are indistinguishable from military reconnaissance flights in terms of orbital parameters and lifetimes. The spacecraft remain in orbit for only two weeks, after which they are recovered, suggesting that they are using film. Although some Western analysts count these as reconnaissance rather than Earth resources missions, this report classifies them as remote sensing since there is no logical reason for the Soviets to specify that these flights, in particular, are for remote sensing, when ordinarily they would simply say nothing about their mission.

The Soviets are also experimenting with advanced sensors for Earth resources sensing in the Meteor 2 series of flights. In 1983, the Soviets launched what may be the first of a new series of remote sensing satellites. Placed in a Sun-synchronous orbit, it was given only a Kosmos designation (K 1484), and no other details were reported. No further launches of this type have been made.

F. SEARCH AND RESCUE

In 1984, the Soviet Union and the members of SARSAT (the United States, Canada and France) signed an agreement providing for the operational phase of the KOSPAS/SARSAT system which is used to locate ships and aircraft in distress. Transponders on Soviet navigation satellites and U.S. NOAA weather satellites pick up signals from emergency locator transmitters on ships and aircraft and relay them to ground stations and control centers in the Soviet Union, United States, Canada, France, Norway and Britain. The Soviet transponders

are developed by the Soviets themselves and are called KOSPAS; the transponders on the U.S. satellites are developed cooperatively by the United States, France, and Canada and are called SARSAT. At the end of 1986, both sides each had two fully functioning transponders in orbit, and the system had been credited with saving over 700 lives. An agreement with INMARSAT to serve as the secretariat for KOSPAS/SARSAT is expected to be signed in 1987.

CHAPTER 4: SPACE SCIENCE

Both the United States and the Soviet Union have sent probes to fly-by, orbit, and/or land on other planets. Other probes investigate the interplanetary medium and/or comets. So far, the United States has sent probes to Mercury, Venus, the Moon, Mars, Jupiter, Saturn, and Uranus, and one is now enroute to Neptune. The Soviet Union has sent probes to Venus, the Moon, and Mars. A U.S. probe already in space was diverted to investigate a comet in 1985; two Soviet probes intercepted Halley's Comet in 1986. Both countries also have programs for earth orbital science.

A. EARTH-ORBITAL SPACE SCIENCE

The history of Earth orbiting satellites for space science studies began with the very first launches of spacecraft. As discussed at the beginning of this report, the decision to launch satellites was made as part of the International Geophysical Year (IGY), and both Sputnik 1 and Explorer 1 were launched in support of the IGY.

The United States has conducted a large number of launches for Earth orbiting space science missions. The Explorer program is a continuing series of small satellites devoted to a particular scientific goal (such as gamma ray astronomy). If successful, the sensors may be adapted and flown on larger, observatory-class satellites. Many of the Explorer missions involve international participation.

By the end of 1986, over 60 Explorer satellites had been flown. Some study the interaction between the Sun and Earth in disciplines such as air density, energetic particles, ionospheric research, magnetospheric research, and solar physics. Other Explorer satellites are dedicated to astronomy, including wavelengths in the x-ray, gamma-ray, ultraviolet, and radio ranges. Larger observatory-class satellites have also been launched by the United States. To date, these have included the Orbiting Geophysical Observatory (OGO), Orbiting Solar Observatory (OSO), Orbiting Astronomical Observatory (OAO), and High Energy Astronomy Observatory (HEAO) programs. The next U.S. observatory-class spacecraft scheduled for launch is the Space Telescope, which will be the first optical telescope in orbit. It was scheduled to be launched by the space shuttle in 1986; it is now scheduled for the fifth shuttle flight after it resumes service.

The Soviet Union launched its first geophysical observatory in 1958 (Sputnik 3), but has not used Earth orbit as a base for

free-flying scientific spacecraft as extensively as has the United States. They launched four Proton satellites in the 1965-1968 time period to study cosmic rays, but although these were large satellites, it is generally thought in the West that the true objective was to test the new launch vehicle which placed these satellites in orbit (the "D" or Proton vehicle), rather than to acquire scientific data. Most of their scientific satellites are designated simply as Kosmos flights and few details are released about them.

The Prognoz program, of which there have been 10 flights since 1971, is the closest the Soviets have come to observatory-class spacecraft performing multiple missions. The first eight of these concentrated on atmospheric studies, but Prognoz 9, launched in 1983, is performing radio astronomy studies. Also in 1983, the Soviets launched the Astron satellite, which is a large observatory-class satellite performing research in the x-ray and ultraviolet wavelengths. Prognoz 10, launched in 1985, is for magnetospheric studies.

Space science research has also been conducted on the space stations launched by both the United States and Soviet Union. For example, the U.S. Skylab carried the Apollo Telescope Mount dedicated to studies of the Sun, and a radio telescope was deployed from Salyut 6. Astronomical studies were conducted on Salyut 1 and 4, and to a small extent on Salyut 7.

B. UNMANNED LUNAR EXPLORATION

The first attempts to send spacecraft to the Moon were either fly-bys or probes that were intended to strike the Moon without surviving the impact. In 1958, the United States began a double series of Pioneer flights--one to photograph the far side of the Moon and the other to fly by it. All four launch attempts in that year failed to reach the Moon. In January 1959, the Soviets launched Luna 1 which apparently missed the Moon. The United States followed in March 1959 with Pioneer 4 which went by the Moon and circled the Sun. U.S. plans then were to follow up with four more, larger Pioneer series lunar orbit flights during the course of 1959 and 1960, but all of these failed to reach even Earth orbit. In fact, a U.S. probe did not reach the Moon until Ranger 4 fell on the far side in 1962.

In September 1959, the Soviet Luna 2 struck the Moon near its visible center, delivering metal plaques bearing the Soviet coat of arms. In October 1959, Luna 3 flew by the Moon and took photographs of the far side, never seen before, which were returned to Earth by radio facsimile. Still later, the U.S. Ranger 7, 8, and 9 flights (1964-1965) returned spectacular TV pictures of the Moon up to the moment that they impacted the lunar surface.

The next phase of unmanned lunar exploration used spacecraft to make survivable landings. The seven U.S. Surveyor spacecraft (1966-1968) returned almost 100,000 pictures of the lunar surface and dug holes in the surface by remote control to determine the chemical composition of the lunar soil.

The Soviet Union attempted landings as early as 1963, but later admitted that Luna 4, 5, 6, 7, and 8 failed to achieve a survivable landing. Additionally, one unnamed flight and Kosmos 60 were lunar failures which did not leave Earth orbit. When Luna 9 in 1966 finally reached the surface, its television camera returned 27 pictures of the surroundings--the first pictures from the surface of another solar system body. Luna 13 performed impact testing of the soil with an extendable arm.

Orbiters were used at about the same time as the landers. The Soviet Luna 10 was the first spacecraft to achieve a successful lunar orbit (1966) and returned data about the composition of the lunar surface and gravity anomalies. Luna 12 in 1966 finally returned a few pictures to supplement earlier Soviet pictures taken of the far side by Luna 3 in 1959 and Zond 3 in 1965. Luna 14 (1968) was an extension of the work of Luna 10, neither of which took pictures. The five U.S. Lunar Orbiters (1966-1967) returned extensive data about the lunar surface that were used to select landing sites for the manned Apollo missions.

The Apollo landings followed the U.S. unmanned lunar program, and no further unmanned missions were launched. The Soviets continued to launch lunar probes until 1976. Zond 5 and 6, the 1968 unmanned precursors to projected later manned flights, returned actual photographs to Earth in the same manner as Apollo 8. Zond 7 in 1969 and Zond 8 in 1970 performed tasks similar to those of the two preceding Zonds. Heavier satellites were placed in lunar orbit (Luna 19 in 1971 and Luna 22 in 1974) which remained under active control for more than a year, gathering a wide variety of data and some pictures.

The Soviet Union launched two special types of lunar vehicles for exploration of the Moon in lieu of human crews. Three missions (Luna 16 in 1970, Luna 20 in 1972, and Luna 24 in 1976) returned a total of approximately 330 grams of lunar material to Earth (compared with 380 kilograms returned by the U.S. Apollo crews). Three other flights that may have been intended to return samples failed (Luna 15, 18, and 23).

The other special Soviet program placed roving vehicles called Lunokhods on the lunar surface. Lunokhod 1 (Luna 17) landed on November 17, 1970, and continued to function until October 4, 1971, traveling 10,540 meters over the surface, and returning 20,000 television views, 200 detailed panoramas, 500 soil-property tests, 25 soil chemical analyses, and a number of astronomical observations with its X-ray telescope. Lunokhod 2 (Luna 21) in 1973 operated for 3 months, but traveled 37,000 meters in that time, and returned proportionately more data and pictures despite its shorter life.

C. U.S. PLANETARY MISSIONS

The U.S. Mariner program of three-axis stabilized probes has involved the launch of ten vehicles, six of which returned planetary data. Mariner 2 and 5 brought back indirect readings of Venus. Mariner 4, 6, 7, and 9 brought back increasingly good pictures of the

surface features of Mars. Mariner 10 not only returned good pictures of the cloud patterns of Venus, but made three photographic passes by Mercury with good results.

The Pioneer series of spin-stabilized spacecraft has seen 18 launch at- tempts, of which 12 were at least partially successful. Pioneer 1 and 3 did not reach their intended trajectories to the Moon, but did send back data about Earth's atmosphere. Pioneer 4 successfully returned data as it flew past the Moon and entered heliocentric orbit. Pioneers 5 through 9 were designed to study the area of space between the Earth and Sun, and did so successfully. Pioneers 6, 7, 8, and 9, launched between 1965 and 1968, were still returning data at the end of 1986.

Pioneers 10 and 11 were the first planetary probes of the Pioneer series, and were launched to investigate Jupiter, Saturn, and the interplanetary medium. Both probes sent back pictures of Jupiter in 1973 and 1974 respectively; Pioneer 10 then was placed on a trajectory out of the solar system, while Pioneer 11 continued on to a successful encounter with Saturn in 1979. Pioneer 10 continues to return data, and in 1983 passed out of the solar system, the first object from planet Earth to do so.

Pioneer Venus 1 and 2 were launched in 1978 and reached Venus in December of that year. Pioneer Venus 1 is an orbiter, which at the end of 1986 was continuing to return data about Venus, and in 1986 also was used to collect data about Halley's Comet. Pioneer Venus 2 consisted of five separate probes, all of which descended through the Venusian atmosphere to make in situ measurements of its characteristics. Although they were not designed to withstand landings on the planet, two of the probes did survive and transmitted data for as long as 67 minutes after impact.

Viking 1 and 2, launched in 1975, each were orbiter/lander combinations. The orbiters mapped the surface of Mars and collected clear views of Deimos and Phobos, the two Martian moons. The landers sent back color pictures from the surface, and their on-board laboratories conducted a search for life with inconclusive results. The last of the viking spacecraft (the Viking 1 orbiter) returned data until 1983. NASA has now turned ownership of that lander over to the Smithsonian Museum.

Voyager 1 and 2 were launched in 1977 toward Jupiter and the outer planets. During 1979, they returned astonishing color pictures not only of Jupiter, but also of its larger moons, each unique and unexpected in appearance. In 1980, Voyager 1 returned equally exciting pictures of Saturn and its moons, including Titan, and Voyager 2 returned data on Saturn in 1981. Voyager 2 reached Uranus in January 1986 and returned more data to astound Earth-bound scientists. Its pictures of the moon Mimas showed virtually every known geological formation on its tiny circumference. Other data about the planet itself led scientists to conclude that Uranus may be surrounded by a superhot ocean of liquid water that does not boil because of atmospheric pressure. If true, then it is the only other

known body in the solar system with liquid water. Voyager 2 will reach Neptune in 1989.

The United States has had several probes to investigate the interplanetary medium. One of special note was launched in 1978 as International Sun-Earth Explorer 3, part of a series of satellites for studying solar-terrestrial relationships. In 1983, it was redesignated ICE, or International Cometary Explorer, and was moved from its position between the Earth and the Sun to fly by Comet Giacobini-Zinner in September 1985. Data from this encounter is being used to compare with that obtained by other spacecraft about Comet Halley. The United States did not have a probe for the Halley's Comet encounter.

D. SOVIET PLANETARY MISSIONS

In 1961, the Soviets launched their first Venus probe, Venera 1, but it was not operating when it reached the planet. In 1962, there were three more Venus attempts and three Mars attempts, with five of these payloads stranded in Earth orbit, and the sixth, Mars 1, not operating when it reached the vicinity of that planet. Zond 1, Venera 2, and Venera 3 were not in operating condition when they reached Venus. Zond 2 made a close fly-by of Mars in a non-operating condition. Zond 3 was a test flight which took pictures of the far side of the Moon and rebroadcast them to Earth as it traveled as far as the orbit of Mars.

Results improved for the Soviets when Venera 4, 5, 6, 7 and 8 all functioned and returned direct readings of Venus' atmosphere. Venera 7 survived a Venus landing and broadcast for 23 minutes from the surface. Venera 8 had similar success, plus performing soil analyses.

In 1975, two larger Soviet Venus probes, Venera 9 and 10, reached their destination and became the first spacecraft to return pictures from the surface of another planet. The orbiters returned pictures and other data for many months in orbit. The landers operated for about an hour on the surface, and their cameras returned good pictures of the far side surface, relayed via the orbiters. This was a remarkable feat, considering the 485 degrees Centigrade temperature and surface pressure 90 times that on Earth.

Venera 11 and 12 were sent to Venus in 1978, at approximately the same time as the U.S. Pioneer-Venus probes. No photographs were returned by these spacecraft, and Soviet scientists have indicated that the imaging systems failed. Data were returned on other aspects of the Venusian atmosphere and surface. Venera 13 and 14 landed in 1982 and sent back color photographs of the surface, and used drills to obtain core samples for chemical analysis.

In 1983, the Soviets launched Venera 15 and 16 which, instead of carrying the traditional landers, were equipped with radars to study the surface of Venus from orbit. Venera 15 entered orbit around Venus on October 10, followed four days later by Venera 16. The radars have a resolution of 1-2 kilometers, and are in polar orbits around the

planet so provide data on parts of the planet not seen by the U.S. Pioneer-Venus orbiter or from Earth-based telescopes.

In December 1984, the Soviets launched two VEGA spacecraft to study both Venus and Halley's Comet. At Venus, the two spacecraft dropped off landers and balloons developed by French scientists which slowly drifted through Venus' atmosphere to make in situ measurements. The main part of each spacecraft continued on to an encounter with Halley's Comet in March 1986. VEGA 1 was the first probe to arrive there; others were launched by the European Space Agency and Japan. These countries, plus the United States, formed the International Halley's Watch for sharing data about comets and assisting in the cometary encounters.

The Soviets have not had very much success with their Mars probes. In 1971, two orbiter/lander spacecraft, Mars 2 and 3, were launched. Mars 2 landed on the surface but no further mention was made of it by the Soviets, suggesting that it failed; Mars 3 made a survivable landing, but signals ceased after 20 seconds, before the first complete picture was received on Earth. The orbiters did return data. In 1973, four spacecraft (Mars 4, 5, 6 and 7) were launched. Mars 4 and 5 were intended as orbiters working with the Mars 6 and 7 landers. Of these four only Mars 5 attained an orbit and Mars 6 a landing. Mars 6 returned direct readings within the atmosphere, but signals ceased before it reached the surface. Thus, only Mars 5 can be counted as a complete success by Western standards.

E. FUTURE U.S. AND SOVIET SPACE SCIENCE MISSIONS

The U.S. space science program was severely set back by the 1986 Challenger tragedy. Three major space science missions--the U.S. Space Telescope, the U.S. Galileo mission to study Jupiter, and the European Ulysses probe to investigate the polar regions of the Sun--were to have been launched in 1986. Between schedule uncertainty once the shuttle resumes service and increased funding difficulties as NASA tries to recover from the tragedy, the space science program is facing what may be its most difficult time.

Space Telescope is currently manifested on the fifth space shuttle mission once the shuttle resumes service. If the shuttle begins flying again in February 1988, Space Telescope would be launched in November 1988. NASA is also building the Gamma Ray Observatory and it is currently scheduled for 1990.

In the planetary area, launch opportunities are determined not only by shuttle availability, but launch windows dictated by planetary alignments. In addition to Galileo and Ulysses, which are now in storage, the United States is building a spacecraft to map Venus (Magellan) and a probe for geophysical and climate studies of Mars (Mars Observer). All were to have been launched by 1990, but the existing shuttle manifest has only three planetary opportunities. The first, in April 1989, is for Magellan. The other two are November 1989 and October 1990. NASA has not yet stated which probes will be launched on these shuttle missions and there may be considerable debate over them. At the end of 1986, NASA was proposing that Mars

Observer be deferred until 1992, but the planetary science community was vigorously opposing such a delay.

Meanwhile, other space science programs that have been discussed for years, such as the Advanced X-Ray Facility and the Comet Rendezvous-Asteroid Flyby (CRAF) mission have not been approved because of budgetary pressure. Several studies have been done in the past few years to recommend the next steps in space science (NASA's Solar System Exploration Committee, and the National Academy of Sciences review of Space Science 1995-2015, for example), but it is unclear when or even if the recommendations will be implemented.

By contrast, the Soviet Union now appears to be focussing more attention than in the past on planetary science, though it should be borne in mind that they have done comparatively little over the history of the space program. Their current plans call for the Phobos mission in 1988, an international program to make detailed studies of the Martian moon Phobos. The Soviet probe will carry a low-power laser which will be used to blast surface particles off Phobos and back toward the spacecraft for analysis. A small lander will also be deposited on Phobos. The mission includes two probes, and if the first is successful, the second may be targeted to the other Martian moon, Deimos. Both spacecraft will also make observations of Mars.

The Soviets plan to send other unmanned probes to Mars through the 1990s. The next is called VESTA and originally was to have flown by Venus and on to the asteroid Vesta. In 1986, the Soviets indicated that they no longer were including Venus on the probe's route, but would send it by Mars instead.

The head of the Soviet Institute for Space Research, Dr. Roald Sagdeyev, has proposed a cooperative mission with the United States for Mars exploration as well. He has suggested that the United States send a rover to Mars that would roam about the surface collecting samples from various locations. The rover would bring the samples back to a Soviet spacecraft that would return them to the vicinity of Earth for analysis (they probably would not be brought back to Earth itself because of contamination concerns). This is not yet an approved mission by either country, although both seem interested in the possibilities. From the U.S. standpoint, the mission would avoid many problems such as technology transfer, since the only place the probes need to be compatible is on the surface of Mars. Also, if either country withdrew from the program for economic, technical, or political reasons, the other would still have a viable scientific mission.

Other Soviet space science plans are not well known. They have discussed plans to launch a satellite for radio astronomy in the 1990s, another program that is being coordinated with Western scientists. In the near future, they apparently will rely on space station crews, and have announced that they will launch an x-ray observatory to dock with Mir in 1987. The instruments were built cooperatively with a British scientist, and Britain has signed an agreement for building a follow-on observatory with the Soviets.

CHAPTER 5: MILITARY SPACE ACTIVITIES

A. MILITARY VERSUS CIVIL SPACE MISSIONS

There is little difference between the Soviet and U.S. space programs as to their general purpose and direction. Both include scientific exploration, technology development and practical applications, using manned and unmanned spacecraft. The satellites support both the military and civilian sectors.

The distinction between military and civilian launches is arbitrary to a certain extent, since any satellite can be used for either sector. For example, communications satellites can carry either military or civilian traffic, and navigation satellites are used by both the military and civilian communities.

When attempting to construct a list of military versus civilian launches, such as table 4, determining which sector will be primarily served by a satellite is complicated. The Soviets, for example, ordinarily do not announce the mission of satellites designated "Kosmos" which comprise more than 85 percent of their annual launches. Western analysts of the Soviet program assess the mission of these satellites based on factors such as telemetry, past experience and the likely nature of a satellite using a particular orbit. In the United States, Transit navigation satellites are developed by the Navy for its use, although over 90 percent of the system's users are civilian. Clearly, distinguishing between military and civilian satellites is an inexact art.

The process is even more complex since table 6 reflects launches rather than individual satellites. The U.S. space shuttle may launch several payloads at one time, and other experiments make take place on the shuttle itself. A Defense Satellite Communications System (DSCS) communications satellite launched from the shuttle would be classified as military, but if the predominant nature of the shuttle mission is civilian, it will be listed as a civilian launch in the table. Only those shuttle missions dedicated to DOD use are counted as military. These difficulties should be borne in mind when using the table.

TABLE 4. Approximate Comparison of U.S. and Soviet Successful Launches: Primarily Civil Versus Primarily Military*

YEAR	PRIMARILY CIVIL		PRIMARILY MILITARY	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.
1957	0	2	0	0
1958	5	1	0	0
1959	5	3	5	0
1960	6	3	10	0
1961	10	6	19	0
1962	21	15	31	5
1963	12	10	26	7
1964	25	15	32	15
1965	35	23	28	25
1966	41	17	32	27
1967	34	20	24	46
1968	25	25	20	49
1969	24	19	16	51
1970	14	26	15	55
1971	22	23	10	60
1972	20	21	11	53
1973	15	28	8	58
1974	18	29	6	52
1975	21	29	7	60
1976	19	25	7	74
1977	15	29	9	69
1978	24	28	8	60
1979	12	27	4	60
1980	8	25	5	64
1981	13	39	5	59
1982	12	33	6	68
1983	15	40	7	58
1984	10	34	12	63
1985	11	33	6	64
1986	3	28	3	63
Total	495	656	372	1,265

* See text for cautionary statements about use of this table. Prepared by CRS.

B. MILITARY SPACE PROGRAMS

The vast majority of military spacecraft satellites is non-aggressive, in fact, their missions are hardly distinguishable from missions conducted for civilian application purposes. Both countries have military satellites for communications, weather, navigation, geodesy, and various types of reconnaissance (photographic, electronic intelligence, nuclear explosion detection, early warning, and ocean surveillance). The only generic type of satellite that the Soviets have for which there is no corresponding U.S. system is radar ocean reconnaissance satellites (RORSATs) which use radars to monitor the oceans. The radars require a great deal of power and the Soviets use nuclear reactors on the satellites to provide that power. For safety reasons, the portion of the satellite containing the nuclear reactor is separated from the rest of the spacecraft and boosted into a very high orbit from which it will not return to Earth until the radioactivity has subsided (hundreds of years). In two cases, however, the system malfunctioned. In 1978, Kosmos 954 reentered prematurely and spread radioactive material over northern Canada. In 1983, Kosmos 1402 reentered in two pieces over the Indian Ocean and the South Atlantic. No increase in radioactivity was detected in either area.

Although the U.S. Government is reluctant to talk about military space activities, there is much speculation about such spacecraft, especially those for photographic reconnaissance. President Johnson, speaking in Nashville, Tennessee on March 15, 1967, claimed in an "off-the-record" statement widely reported at the time that the dividends of military space operations to the United States were equal to ten times everything which had been spent on space. This implied savings in the defense budget over a ten year period on the order of $400 billion, because of more precise information about military and related activities all over the world. President Carter on October 1, 1978, officially acknowledged the U.S. role in military photoreconnaissance from space. The Soviet Union does not readily discuss its activities in this area either, although there is no doubt that they have a substantial investment in satellite reconnaissance.

C. SPACE WEAPONS

There is one special category of military space activities which can be described as "aggressive" and these are space weapons. Considerable debate has developed as to whether space weapons, either those based in space for use against ground, air or space targets, or those based in the air or on the ground for use against space targets, will lead to greater or less stability between the superpowers. Although they have become a matter of increasing debate in the past several years, space weapons have existed since the earliest days of the space program.

1. Early U.S. and Soviet Antisatellite Programs

The first test of an antisatellite (ASAT) device was conducted by the United States in 1959. A Bold Orion air-launched missile was used

to score a deliberate near miss on the U.S. Explorer 6 satellite. Although the Bold Orion was not pursued as an ASAT device, the United States did have plans for a program called SAINT (variously described as having stood for SAtellite INspecTor, SAtellite INTerceptor, or SAtellite Inspection and NegaTion) from 1960-1962, but this program also was cancelled.

In 1962, Nikita Khrushchev stated in an interview with American newspaper editors that the Soviet Union had a missile that could "hit a fly in outer space." This was interpreted by some as an indication of an ASAT capability, perhaps using Galosh antiballistic missiles. Perhaps in response to this concern, or perhaps because of the FOBS program (see below), the United States developed its own ASAT system using missiles based on Johnston Island and Kwajalein Atoll in the Pacific. The system at Kwajalein, which used Nike-Zeus missiles, was terminated in 1964, while the Johnston Island system, using Thor missiles, was declared operational by President Johnson in a 1964 speech. These facilities are believed to have been shut down in 1975. Since the system employed nuclear warheads, its use would have violated the 1963 Limited Test Ban Treaty and the 1967 Outer Space Treaty. The Soviet Galosh system may still be capable of intercepting satellites to about the same degree as the United States could have from its mid-Pacific installation, and similarly would violate the 1963 and 1967 treaties if used.

2. The Soviet Co-Orbital ASAT Device

Beginning in 1968, the Soviets began testing a co-orbital ASAT device; a total of 20 tests have been conducted so far. The most recent test was in June 1982, and the Soviet Union subsequently announced a unilateral moratorium on ASAT testing, stating that it will not be the first to place ASAT weapons in orbit (but avoiding any admission that they have already tested an ASAT device). The interceptor is launched by a variant of the Scarp booster and goes into a close co-orbit with the target satellite. In operation, the interceptor would then maneuver close to the target and explode (using a chemical explosive), destroying the operational capability of the target with shrapnel. Nicholas Johnson, in his annual report "Soviet Year in Space" (Teledyne Brown Engineering, Colorado Springs, Colorado), lists 9 of the 20 tests as successes.

Tests were conducted from 1968 to 1971, after which a four-year hiatus occurred. Testing resumed in 1976, the year after the U.S. dismantled its missile ASAT system, and the Chinese had orbited their first prototype reconnaissance satellite. Whether these factors led to the resumption in testing, or whether the Soviets introduced a system with new technology at that time, is unknown. The United States declared the Soviet system operational in 1977 and decided to develop its own advanced ASAT (see next section). At the same time, President Carter called on the Soviets to negotiate a treaty to ban weapons from space, and during the course of those talks in 1978-1979, the Soviets once again ceased tests of their ASAT device. When the negotiations ended (following the Soviet invasion of Afghanistan in late 1979), the ASAT tests resumed, with one test in 1980, two in 1981, and one in 1982. Whether or not the system should still be

considered operational, after five years of dormancy, is open to question.

The Soviet system is limited by the altitudes and inclinations at which it can be used. U.S. communications and early warning satellites are currently outside the range of the Soviet co-orbital ASAT, although future developments (such as using a more capable launch vehicle) could enhance its range.

3. U.S. F-15 ASAT Device

In 1977, following the Pentagon's assessment that the Soviet ASAT system was operational, President Carter authorized DOD to develop a U.S. ASAT device. Unlike the Soviet system, which is launched from the ground like a typical satellite, the U.S. ASAT device, called a Miniature Homing Vehicle (MHV), is launched from a two-stage rocket attached to an F-15 aircraft. With this mobility, it can go to the satellite that is to be attacked, rather than waiting for the satellite to be in a correct orbital position to be intercepted from a ground launch site. The MHV would destroy its target by direct impact, and does not carry any explosive material. The U.S. ASAT system is still being developed and has encountered stiff congressional opposition which has limited the amount of testing permitted. Five tests have been conducted: four (two in 1984 and two in 1986) against points in space; one (in 1985) against an object (an obsolete U.S. satellite). Congress has legislated several bans prohibiting tests against objects in space, although tests against points in space are permitted. The 1985 test against an object came after President Reagan submitted certain congressionally mandated certifications. For FY87, Congress has banned tests against objects in space until and unless the Soviet Union conducts a test of a dedicated ASAT device.

The U.S. ASAT is limited in altitude, but its range is classified. According to DOD statements before Congress, the range is less than the Soviet ASAT (reported by DOD to be at least 5,000 kilometers), but it can attack satellites at any inclination. Soviet communications and early warning satellites are in different orbits than their American counterparts, with a low point only 500 kilometers above the surface. These probably are within range of the U.S. ASAT, although the low point of the orbit is over the ocean, so the F-15 might require in-flight refueling to reach the satellite, and the F-15s would have to be based in the Southern Hemisphere. Also, the Soviet satellite would be travelling at a very high velocity at that point, making an intercept extremely difficult.

4. Future Antisatellite Devices

The Pentagon asserts in its annual report "Soviet Military Power" that the Soviet Union has ground based lasers with the potential for damaging some components of U.S. satellites, although the report is not specific about which components of what satellites. Ground and space based lasers are potential ASAT weapons for both countries. The United States, as part of the Strategic Defense Initiative program, is developing laser weapons. Using them in an antisatellite mode is

easier than for attacking incoming ballistic missiles (the purpose of the SDI program) and it is possible that they will be tested in the ASAT mode first. The Air Force has indicated interest in developing ground-based laser ASATs, although no funding has been directed at this effort through FY86.

5. Soviet Fractional Orbital Bombardment System (FOBS)

Although no country has placed nuclear weapons in orbit to date, the Soviets tested a system from 1967-1971 called a Fractional Orbital Bombardment System (FOBS) which could be considered such a device if it had become operational. FOBS was essentially a long range ICBM which would have approached the United States from around the South Pole, rather than the North Pole, thus avoiding the Ballistic Missile Early Warning System (BMEWS) radars which point to the north. This was not a technical violation of the 1967 Outer Space Treaty, which bans placing nuclear weapons in orbit, because there is no reason to assume they carried nuclear material on board the test flights, and the dummy warhead flew less than one full orbit.

Opinion is divided in the West as to whether the Soviets ceased testing the FOBS system in 1971 because they determined it was not worthwhile, or because it is operational. Two facts have become available in recent years which tend to support the thesis that the system was judged to be of little value. In the 1979 SALT II agreement (which was never ratified), the Soviets agreed to dismantle 18 "fractional orbital missile launchers" at Tyuratam, an apparent reference to FOBS. The fact that they were willing to give them up suggests that they were not considered terribly valuable. Second, in its report on the FY 1985 authorization bill for DOD, the House Armed Services Committee reported that the reason the United States had developed an antisatellite system in the 1960s was because of concern about FOBS, and that when FOBS "was not deployed," the United States dismantled its ASAT system. There is some question as to whether this conclusion is correct since only the FOBS test flights flew over the site at which the U.S. ASAT system was based; if FOBS had been used operationally it would have had to fly a completely different trajectory to hit the United States and could not have been intercepted from Johnston Island. Nevertheless, the comment that the U.S. ASAT system was dismantled because FOBS was not deployed strengthens the supposition that the FOBS program was not successful.

E. CONCERNS ABOUT THE MILITARIZATION OF SPACE AND "STAR WARS"

In the early 1980s, concern began to grow about the apparent "militarization" of space, that is, the increasing use of space for military purposes, particularly weapons. As noted above, the 1978-79 negotiations initiated by President Carter to ban weapons from space were unsuccessful. In 1981, the Soviets introduced a draft treaty at the United Nations, but a close reading showed that it would ban only the stationing of weapons in space, and since neither the existing Soviet ASAT nor the U.S. system in development is stationed in space, the treaty would have had little impact. No negotiations were held on this text.

In March 1983, President Reagan made a nationally televised address in which he called for research into technologies that could defend the United States and its allies against ballistic missile attacks. His advisers stated
that these systems could be based on the ground, or in space, leading the media to dub this the "Star Wars" speech. Concern about the militarization of space intensified following the President's address, and the initiation of testing of the U.S. ASAT device.

In August 1983, the Soviets introduced a revised draft treaty at the U.N. which would ban the use of force in space, a much broader scope than the earlier draft, thereby prohibiting both ASAT and ballistic missile defense activities in orbit, although space-based BMD is already banned by the 1972 ABM Treaty.

During 1984, the potential for U.S./Soviet negotiations on space weapons dominated the headlines for many months. On June 29, the Soviets formally offered to hold talks with the United States on space weapons beginning that September in Vienna. After several weeks of charges and countercharges that each side was setting unacceptable preconditions (the Soviets wanted the United States to agree to a moratorium on ASAT testing; the United States wanted the Soviets to agree to return to the negotiating table on offensive weapons), no talks were scheduled. In 1985, however, bilateral talks resumed in Geneva on intermediate nuclear forces and strategic arms reduction, and space weapons were added as a third aspect of the discussions. These talks were continuing as of February 1987. In the fall of 1986, President Reagan and Soviet President Gorbachev met at a "mini-summit" in Iceland to discuss arms control and especially the SDI program, but no agreements were forthcoming.

CHAPTER 6: SPACE PROGRAM MANAGEMENT AND RESOURCES

A country's ability to routinely place satellites in orbit depends on supporting resources within that country. Among the most frequently asked questions in this regard are how much the United States and Soviet Union spend on space activities, how the respective programs are managed, and how they compare with respect to launch sites and launch vehicles.

A. SPACE EXPENDITURES OF THE U.S. AND U.S.S.R.

The United States has spent about $215 billion on the space program in the several agencies of Government involved (NASA, Departments of Defense, Energy, Commerce, Interior, and Agriculture, and the National Science Foundation) from FY59 to FY86 (these are current dollars unadjusted for inflation).

The Soviet Union does not publish space budget data and estimating what they spend is complicated by uncertain ruble to dollar exchange rates, the lower cost of labor in the Soviet Union, and the fact that most of their spacecraft are produced in large numbers, thus reducing the cost per spacecraft. Thus, even though the Soviets may launch five or six times more often than the United States, they are not necessarily spending five or six times more to do so. In 1982, a U.S. Government estimate was made suggesting that the Soviets spent $18 billion in 1982 (or about 50 percent more than the $13 billion spent in the United States that year) on its space program. The 1984 edition of DOD's "Soviet Military Power," estimated that the Soviets would spend $22 billion on their space program in 1985, but these figures did not include operations and maintenance. The United States spent $20 billion in FY85 on space activities, including operations and maintenance.

B. MANAGEMENT OF SPACE PROGRAMS

Under the terms of the National Aeronautics and Space Act (NASAct) of 1958, the United States has separate military and civilian space programs. Civilian activities are under the jurisdiction of the National Aeronautics and Space Administration (NASA), while the Department of Defense (DOD) conducts military space activities. U.S. Space Command in Colorado Springs, Colorado coordinates the operational aspects of space activities by all services; the Air Force and Navy also have separate Space Commands. The Army has a Space Council. Other U.S. space activities are conducted by the Departments of Energy, Commerce, Transportation, Agriculture and Interior, and the State Department is involved in international policy aspects of space.

NASA and DOD together represent more than 95 percent of the U.S. space program budget.

The National Aeronautics and Space Council, a coordinating body in the Executive Office of the President, was created in the NASAct to coordinate space policy on a Government-wide basis. It was abolished by President Nixon in 1973. President Reagan created a Senior Interagency Group/Space (SIG/Space) to coordinate U.S. space activities during his Administration, which reports to the National Security Council.

The Soviet space program was operated entirely by the Strategic Rocket Forces until 1985 when a "civilian" space agency called Glavkosmos was created. The Strategic Rocket Forces are still responsible for actually launching spacecraft and almost certainly retain full responsibility for military space activities. Glavkosmos has been described by the Soviets as being responsible for building spacecraft and operating them once they are in orbit (including the Salyut and Mir space stations), as well as for commercial and international agreements. The Soviet Academy of Sciences and its institutes remain responsible for building the scientific experiments for Soviet spacecraft, and the Interkosmos Council retains responsibility over international scientific experiments, although the agreements with other countries for conducting joint space activities are now negotiated by Glavkosmos.

C. LAUNCH SITES

The United States has its major launch site at Cape Canaveral, Florida for manned, lunar, and planetary launches, and for launching satellites to geostationary orbit (primarily for weather and communications). It has a second launch site at Vandenberg Air Force Base, California, for satellites which must go into polar orbits (primarily weather, Earth resources, navigation, and reconnaissance). A third minor site for small payloads is at Wallops Island, Virginia. Short-range vertical testing is done at White Sands, New Mexico, although orbital launches are not conducted there.

The Soviet Union has developed launch sites very similar to the United States. The major site for manned, lunar, planetary, and geostationary satellites is near Tyuratam in Kazakhstan. The Soviets call it the Baykonur Cosmodrome, but it is about 370 kilometers from the town of Baykonur. A second, largely military site is near Plesetsk in the Arctic. The third site is located near Kapustin Yar from which launches of vertical probes (like White Sands) and small orbital payloads (like Wallops Island) are made.

Table 5 summarizes the number of launch successes from all launch sites in the world. Woomera and Hammaguir (used by the French for early launches of the Diamant booster) have been inactive for many years; Kourou is the site of launches using the Ariane launch vehicle and was used previously by the French for Diamant. The Indian Ocean Platform is used infrequently by Italy for launches using U.S. rockets.

TABLE 5. World-Wide Successful Space Launches By Site

Launch Site	1986	1957-1985	Total
Plesetsk (U.S.S.R.)	56	1,055	1,111
Tyuratam (U.S.S.R.)	35	693	728
Vandenberg AFB (U.S.)	3	466	469
Cape Canaveral (U.S.)	3	368	371
Kapustin Yar (U.S.S.R.)	0	82	82
Kourou (Guyana)	2	18	20
Wallops Island (U.S.)	0	19	19
Uchinoura (Japan)	0	16	16
Tanegashima (Japan)	2	13	15
Shuang Cheng-tzu (China)	1	13	14
Indian Ocean Platform (Kenya)	0	8	8
Hammaguir (Algeria)	0	4	4
Sriharikota (India)	0	3	3
Xichang (China)	1	2	3
Woomera (Australia)	0	2	2
Total	103	2,762	2,865

Prepared by CRS using data from trade magazines such as Aviation Week and Space Technology and Aerospace Daily, and from Geoffrey Perry of the Kettering Group.

D. LAUNCH VEHICLES

The United States has used launch vehicles scaled to lift payloads from as light as 9 kilograms up to the Saturn V which could carry over 136,000 kilograms to low Earth orbit. In its manned programs, the Mercury spacecraft were launched to orbit by Atlas (the suborbital flights used the Redstone rocket); Gemini by Titan II. Several Earth orbital Apollo flights were launched by Saturn IB; the lunar Apollos used the Saturn V.

The Saturn family of vehicles is no longer produced. The United States currently has the following families of "expendable" launch vehicles, which can only be used once: Scout, Delta, Atlas, and Titan. The only reusable launch vehicle in the world is the U.S. space shuttle which is currently grounded (at the end of 1986 the Titan was also grounded due to launch failures in 1985 and 1986). The newest member of the Titan family, which will be called the Titan IV, should be available in 1988. The Air Force announced in 1986 that it would contract for two new launch vehicles: a "medium launch vehicle" which will be based on an existing design, and a "heavy lift launch vehicle" which may or may not be based on an existing design. In addition, the United States has begun a research and development program on an aerospace plane (formerly called the transatmospheric vehicle) which could serve both as an aircraft and a spaceplane. It is not expected that an aerospace plane will be operational before the year 2000.

In 1957 the Soviet Union started to use its original ICBM, with an orbital lift capacity of 1,360 kilograms. The same basic "A" vehicle is in use today with upper stages added to improve performance. Like the United States, the Soviet Union has a variety of different launch vehicles capable of lifting different size payloads into orbit. The Soviet vehicles have several designations in the West. Some refer to them with SS numbers, others with SL numbers, and still others with names. Charles Sheldon, the late Congressional Research Service specialist who originated this series of reports, developed his own alpha-numeric system which is also widely used. This system designates the vehicles with the letters A, B, C, D, and F in the order in which they entered service for space launches. Upper stages are designated e, h and m. Numbers differentiate various combinations of stages. Thus, there may be D-1 launches, or D-1-e if a particular type of upper stage is added; F-1-m or F-2 vehicles, again depending on the particular configuration. (The "C" designation was used for a vehicle the Soviets attempted to develop in the late 1960s for their lunar program, but it never flew successfully. There is no "i".) Details of this designation system can be found in the Soviet Space Program reports prepared by CRS and published by the Senate Commerce, Science and Transportation Committee.

The A vehicle has been used throughout the history of the Soviet space program for launches related to the manned program (both for carrying crews into orbit and separate cargo flights). The "C" vehicle is the smallest is the fleet, while the Proton or "D" launch vehicle is the largest. They have not yet developed a launch vehicle as capable as the Saturn V.

By Soviet accounts, several of their launch vehicles use liquid oxygen and a kerosene derivative for the first stages (as do many of those of the United States), and use fairly conventional storable fuels for upper stages. The new SL-X-16 or "J" medium lift launch vehicle may be the long awaited transition to the use of dual cryogenic fuel (liquid hydrogen/liquid oxygen), used in U.S. launch vehicles such as the Saturn V and space shuttle, the European Ariane, and China's Long March 3. According to the 1986 edition of the Pentagon's Soviet Military Power report, the J vehicle was flight tested in 1985. Geoffrey Perry, head of the Kettering Group of space observers, has concluded that the J vehicle was used twice in 1986. The Pentagon also reports that the Soviets are developing a "heavy lift" launch vehicle that will have a lift capability similar to the Saturn V. Reports in Aviation Week and Space Technology state that the J vehicle is a component of the larger heavy lift vehicle. It is expected that this heavy lift vehicle will be used to launch the Soviet space shuttle.

The United States has developed solid-fuel rockets mostly for military missile purposes, and certain space upper stages. The small Scout rocket is solid fuel in all stages, and strap-on boosters using solid fuel are used with Titan variants and the space shuttle. There is no evidence that the Soviets use solid-fuel boosters in their space program, although they may have some for missile use.

As discussed earlier, the United States is now performing research and development on an aerospace plane through the NASP program. The Soviet "spaceplane" is not like this aerospace plane. Rather, it is simply a smaller version of a space shuttle, and would be launched conventionally on top of a rocket. It is not known if the Soviets are also working on a vehicle such as the NASP.

The United States experimented with components for a nuclear rocket as an upper stage for Saturn in the 1960s. A solid core reactor would heat hydrogen to be expelled from the nozzle. The work was cancelled because of budgetary constraints and the lack of missions for which such propulsion would be needed. There is no evidence that the Soviets are developing nuclear rockets, although it is not likely that they would announce such efforts if they were pursuing such research.

Table 6 summarizes world-wide use of basic vehicles for successful launches to Earth orbit and beyond. Further details on launch vehicles used by other countries can be found in part II.

TABLE 6. World-Wide Successful Launches By Basic First Stage

Name	Country	Vehicle Origin	1986	1957-1985	Total
Sapwood (A)	USSR	missile (SS-6)	45	1,063	1,108
Delta	USA	missile (Thor)	1	379	380
Skean (C)	USSR	missile (SS-5)	15	318	333
Scarp (F)	USSR	missile (SS-9)	21	187	208
Atlas	USA	missile	3	201	204
Titan	USA	missile	0	146	146
Sandal (B)	USSR	missile (SS-4)	0	144	144
Proton (D)	USSR		8	118	126
Scout	USA		1	76	77
Space Shuttle	USA		1	23	24
Mu	Japan		0	15	15
"N"	Japan	missile (Thor)	1	13	14
Ariane	ESA		2	12	14
Saturn 5	USA		0	13	13
Saturn 1	USA		0	13	13
FB-1	China	missile (CSS-X4)	1	11	12
Diamant B	France		0	6	6
Redstone	USA	missile	0	4	4
Jupiter	USA	missile	0	4	4
Diamant	France		0	4	4
Vanguard	USA		0	3	3
SLV-3	India		0	3	3
Long March 3	China		1	2	3
Long March 1	China	missile (CSS-2)	0	2	2
SL-X-16 (J)	USSR		2	0	2
Lambda	Japan		0	1	1
Black Arrow	U.K.		0	1	1
H	Japan		1	0	1
Total			103	2,762	2,865

Prepared by CRS using data from trade magazines such as Aviation Week and Space Technology and Aerospace Daily, and from Geoffrey Perry of the Kettering Group.

CHAPTER 7: FUTURE DIRECTIONS

Attempting to predict the future of the U.S. space program is a difficult assignment as it depends upon political decisions as much as on technical capabilities, both of which are virtually impossible to foretell. There are more engineering possibilities than there are financial resources likely to be made available to pursue them. There are many paper plans, but they remain on paper until the President and the Congress agree on the plans and funding.

Estimating what the Soviet Union will elect to do in space is difficult, too, for all those reasons plus trying to peer through their veil of secrecy. The Soviets have stated very long term goals (such as colonizing other planets), but have not elaborated on time frames. They, too, undoubtedly have to face hard budget choices before actual hardware work can begin.

Nevertheless, it seems useful to identify some of the possibilities facing both countries in the longer term future.

A. 1986 REPORT OF THE NATIONAL COMMISSION ON SPACE

In 1984, Congress decided that it was time to appoint an outside panel to look at the long-term future of the U.S. civilian space program. Language in NASA's FY85 authorization bill directed President Reagan to establish a National Commission on Space, with 15 members, to spend one year developing recommendations on where the space shuttle and space station programs should lead the United States. The legislation specified that the Commission take as given both those programs, and that it not address military space activities.

President Reagan officially established the Commission in October 1984, but did not name the 15 commissioners until March 1985. Chaired by former NASA Administrator Thomas O. Paine, the Commissioners spent one year assessing what the country wanted its space program to do for them, and making recommendations about how to satisfy those needs. Fifteen public forums were held across the United States to solicit input from citizens; monthly meetings were held at which experts could testify to the Commission on their ideas about future space programs; and letters were sent to a wide variety of well-known individuals (in and outside of the space community) in the United States asking for their input as well.

From this and their own expertise, the Commissioners developed a 50-year plan for the United States in their report Pioneering the

Space Frontier. In summary, the Commission called for the United States to lead the way in opening the inner solar system for science, exploration, and development. In doing so, the Commission envisioned establishment of bases on the Moon and Mars, and creation of a routine transportation system among the Earth, Moon and Mars. The Commissioners emphasized that they were not trying to predict the future, but rather to show what the United States can do if it so chooses.

One area which the Commissioners felt was of critical importance was developing low cost access to space. They concluded that in order to achieve low cost, different vehicles should be developed for taking people and cargo into space. For cargo transport, they recommended that the private sector be closely involved in developing the next generation launch vehicle so that it can be operated by the private sector rather than the Government. They left open the question of whether it should be derived from existing technology or completely new. For transporting people (and high value cargo) they concluded that aerospace plane technologies (see chapter 2) and advanced rocket technologies should be developed over a five year period, after which a decision could be made as to which was the better approach.

Once these vehicles are available, a "Highway to Space" would be established, permitting routine, low-cost access to Earth orbit and the Moon (using transfer vehicles from Earth orbit). The Commission envisioned people returning to the Moon by 2005 and establishing first outposts, and later settlements there from which people could mine lunar resources and conduct scientific experiments (astronomers, for example, are anxious to place observatories on the far side of the Moon where they will be shielded from the interference created by humans on Earth).

To reach Mars, which the Commissioners suggest for the year 2015, a "Bridge between Worlds" would be created. The Commissioners believed that an approach different from the Apollo program should be used when sending people to Mars. Instead of going for a few days, collecting samples, and returning home, the Commissioners recommended routine access to Mars, which, like the Moon, would be a site for science, exploration, and resource development. Thus, the Commissioners envisioned two cycling spaceships on interlacing, repetitive trajectories between the Earth and Mars. Travel time to and from Mars would be approximately six months, and stay time on Mars could be as long as a year.

The report details a program involving both manned and unmanned activities, acting synergetically to achieve the goal of opening the inner solar system. Throughout the process, the Commission envisions the private sector following the Government and taking over operation of space facilities, for example, and making lucrative businesses out of resource operations. Although the Commission recognized that the Government would have to pave the way, it fully expected the private sector to follow. The Commission also expressed the hope that its recommendations would galvanize the most creative minds throughout the world to accomplish the goals in the report. Thus, they recommend

that the United States lead the way in this area; not that we do it alone.

During 1986, Congress responded positively to the Commission's report in the sense that it set a long term goal for the civilian space program. In light of the Challenger tragedy, however, attention is now focussed on near term problems in getting the space shuttle safely back into operation and the relative roles of the space shuttle and expendable launch vehicles in placing satellites in orbit. In the executive branch, although the President has not yet commented on the report, NASA is developing an implementation plan which should be ready early in 1987.

B. LONG TERM SOVIET PLANS

As for the Soviet Union, it would not be unexpected to see them send crews to the Moon eventually, since their goals in space are so broad and long range. If Western analysts are correct that the Soviets lost the Moon race because they did not have hardware capable of accomplishing the task, then the attempt might be made once hardware (for example, the heavy lift launch vehicle) becomes available.

The Soviet Union has spoken quite positively about manned flight to the planets and it is hard to doubt their ultimate intentions in this regard if one studies their total program effort. Carrying out such flights will confront them with the same technical and financial questions which the United States would face. Nevertheless, they have frequently stated that one of the reasons they are extending the duration of manned missions in Earth orbit is to obtain data on human reaction to spaceflight conditions so someday they can send men to Mars (although they have never said they would land on the planet). On October 18, 1984, at the end of the record setting 237 day flight on Salyut 7, the Soviet press agency TASS directly tied that duration to the length of time it would take to send a crew to Mars. Also, President of the Soviet Academy of Sciences Anatoliy Alexandrov stated on November 2, 1984, that sending people to Mars was technically feasible already, but that problems involving logistics (food, water, and fuel supply) had to be overcome. Roald Sagdeyev, head of the Institute of Space Research in the Soviet Academy of Sciences has been repeatedly quoted as saying that manned missions to the Moon and Mars will not occur before the year 2000.

C. COOPERATION BETWEEN THE UNITED STATES AND SOVIET UNION

In 1984, the prospect of a joint U.S./Soviet manned flight to Mars as an alternative to an "arms race in space" was introduced at hearings by the Senate Foreign Relations Committee on a resolution introduced by Senator Matsunaga. The resolution (S. J. Res. 236) was enacted into law (P.L. 98-562), but called primarily for a resumption of the U.S./Soviet agreement for space cooperation in general.

While the main feature of the relationship between the United States and Soviet Union in space has been competition, the two countries have also cooperated throughout the years as well. The most

long-standing and successful cooperative arrangements have involved the exchange of scientific data from planetary programs and on space biology. Five major treaties concerning space activities have been negotiated at the United Nations and four have been signed by both countries (the fifth, called the Moon Treaty, has not been signed by either).

The future of U.S./Soviet cooperation has been clouded by international tensions. After the imposition of martial law in Poland in late 1981, President Reagan announced sanctions against the Soviet Union for the role it is believed to have played in that situation. Among the actions taken by President Reagan was the announcement that the United States would not renew scientific agreements with the Soviet Union, including the space cooperation agreement which expired in May 1982. Two projects (the biosatellite mission launched in 1983 and the KOSPAS/SARSAT search and rescue satellite program) which were begun while the agreement was in force were continued, however, and both countries cooperated with the European Space Agency and Japan in ground and space-based studies of Halley's Comet.

In June 1984, President Reagan announced that he would try to reach agreement with the Soviets on a joint space rescue mission that would involve a simulated mission between the U.S. space shuttle and the Soviet Salyut space station to demonstrate the ability of each side to rescue the other's space crews. He signed the Matsunaga resolution that fall.

During this time, the Soviets linked cooperation in space with cancellation of the Strategic Defense Initiative, arguing that they could not cooperate in space with a country attempting to militarize it. In the summer of 1986, however, the Soviets suddenly decoupled the two issues, and talks about renewed civilian space cooperation were held that fall. The first round was held in September in Moscow and, despite the cool relations between the two countries because of the U.S. arrest of an alleged Soviet spy and the subsequent Soviet arrest of a U.S. reporter, enough progress was made that the topic was discussed again at the Iceland mini-summit between President Reagan and Premier Gorbachev. Although no arms control agreement developed from the Iceland talks, a draft agreement on space did. It was finalized in draft form in Washington several weeks later, again despite chilly relations during a period when each country expelled the other's diplomats. That the space agreement was worked out during such tense times attests to the importance each country attaches to it. The exact details of the agreement have not been released, and it is awaiting signature at the next Reagan-Gorbachev summit.

CHAPTER 8: TABLE OF SPACE "FIRSTS"--U.S. AND SOVIET

Any attempt to compare the relative pace of the two principal space programs through a table of "firsts" has certain weaknesses, as it does not answer by how many days or years a particular event occurred in one country before another. Further, it does not distinguish between a nominal first accomplishment in crude form by one country, sometimes followed by a much more impressive and elaborate follow-up by the other country. Nonetheless, such firsts do affect public opinion, and analysis by various fields of endeavor may give some sense of relative direction of pacing efforts in each country. Table 7 attempts such a measure.

TABLE 7. Major U.S. and Soviet Space "Firsts"

United States		
Event	Satellite	Launch Date
Bio and Manned Flight		
Manned orbital maneuver	Gemini 3	03/23/65
Controlled extravehicular activity	Gemini 4	06/03/65
Manned space rendezvous	Gemini 6, 7	12/04/65
Manned docking with unmanned vehicle	Gemini 8-Agena	03/16/66
Manned lunar orbit	Apollo 8	12/21/68
Manned lunar return reentry	Apollo 8	12/21/68
Lunar orbit rendezvous	Apollo 10	05/18/69
Lunar landing and return	Apollo 11	07/16/69
Manned lunar rover	Apollo 15	07/26/71
28-day flight	Skylab 2	05/25/73
59-day flight	Skylab 3	07/28/73
84-day flight	Skylab 4	11/16/73
International docking	Apollo	07/15/75
Flight of reusable vehicle	STS 1	04/12/81
4-person crew	STS 5	11/11/82
5-person crew	STS 7	06/18/83
6-person crew	STS 9	11/28/83
Untethered EVA	STS 41-B	02/03/84
In-orbit satellite repair	STS 41-C	04/06/84
7-person crew	STS 41-G	10/05/84
Satellite retrieval/return	STS 51-A	11/08/84
8-person crew	STS-61-A	10/30/85
Science*		
Van Allen radiation belts	Explorer 1	02/01/58
Earth shape measured	Vanguard 1	03/17/58
Orbiting solar observatory	OSO 1	03/07/62
Data from Venus	Mariner 2	08/27/62
Geodetic satellite	Anna 1B	10/31/62
Lunar close-up pictures	Ranger 7	07/28/64
Mars pictures	Mariner 4	11/28/64
Micrometeorite satellite	Pegasus 1	02/16/65
Lunar orbit pictures	Orbiter 1	08/10/65
Lunar trenching	Surveyor 3	04/17/67
Color picture of full Earth face	DODGE	07/01/67
Lunar soil chemical analysis	Surveyor 5	09/08/67
Live lunar TV broadcast	Apollo 8	12/21/68
Return of lunar rocks	Apollo 11	07/16/69
Color pictures of Jupiter	Pioneer 10	03/03/72
Color pictures of Saturn	Pioneer 11	04/06/73
Radiotelescope in lunar orbit	Explorer 49	06/10/73
Pictures of Venus	Mariner 10	11/03/73
Pictures of Mercury	Mariner 10	11/03/73
Solar Probe	Helios 1	12/10/74
Mars surface pictures	Viking 1	08/22/75
High energy astronomy observatory	HEAO 1	08/12/77
Detailed Surveys of Jupiter's Moons	Voyager 1	09/05/77
Detailed Surveys of Saturn's Moons	Voyager 1	09/05/77
Pictures of Uranus and its Moons	Voyager 2	08/20/77
Comet intercept (Giacobini-Zinner)	ICE	08/12/78

TABLE 7. Major U.S. and Soviet Space "Firsts"--continued

Union of Soviet Socialist Republics

Event	Satellite	Launch Date
Bio and Manned Flight		
Animal in space (dog)	Sputnik 2	11/03/57
Animal in space, recovered	Korabl Sputnik 2	08/19/60
Man in space, recovered	Vostok 1	04/12/61
Women in Space, recovered	Vostok 6	06/16/63
Multi-manned spacecraft	Voskhod 1	10/12/64
Extravehicular activity	Voskhod 2	03/18/65
Recovery, circumlunar live animals	Zond 5	09/21/68
Manned docking with another manned ship	Soyuz 4/5	01/14/69
18-day flight	Soyuz 9	06/01/70
Space station	Salyut 1	04/19/71
24-day flight	Soyuz 11	06/06/71
International docking	Soyuz 19	07/15/75
96-day flight	Soyuz 26/27	12/10/77
2 ferry craft docked to station	Soyuz 26/27	01/10/78
International crew launch	Soyuz 28	03/02/78
140-day flight	Soyuz 29/31	06/15/78
175-day flight	Soyuz 32/34	02/25/79
185-day flight	Soyuz 35/37	04/09/80
211-day flight	Soyuz T-5/T-7	05/13/82
Construction in space	Soyuz T-9	06/27/83
237-day flight	Soyuz T-10/11	02/08/84
Woman EVA	Soyuz T-12	07/17/84
Crew Rotation	Soyuz T-13/T-14	09/00/85
Ferry between space stations	Soyuz T-15	03/13/86
Science*		
Orbiting geophysical lab	Sputnik 3	05/15/58
Farside lunar picture	Luna 3	10/04/59
Cosmic ray measurements	Proton 1	07/16/65
Pictures from lunar surface	Luna 9	01/31/66
Lunar surface bearing test	Luna 13	12/21/66
Venus atmospheric probe	Venera 4	06/12/67
Automated return of lunar sample	Luna 16	09/12/70
Automated lunar roving laboratory	Luna 17	11/10/70
Venus soil analysis	Venera 8	03/27/72
Venus surface pictures	Venera 9	06/08/75
Radio telescope 10-meter dish	Salyut 6	09/29/77

*This table shows launch dates rather than the date of the event described. This is particularly important to remember with the science missions, since the event may occur years after launch. For example, Voyager 2 was launched in 1977, but encountered Uranus in 1986.

TABLE 7. Major U.S. and Soviet Space "Firsts"--continued

United States

Event	Satellite	Launch Date
Civil and Military Applications		
Active communications	Score	12/18/58
TV pictures from space	Explorer 6	08/07/59
Weather satellite	Tiros 1	04/01/60
Navigation satellite	Transit 1B	04/13/60
Missile detection	Midas 2	05/24/60
Observation recoverable flight	Discoverer 13	08/10/60
Passive communications	Echo 1	08/12/60
Operational synchronous communications	Syncom II	07/26/63
Nuclear explosion detection	Vela Hotel	10/17/63
Earth resources satellite	ERTS 1	07/23/72
Synchronous 24-hour weather	SMS 1	05/17/74
Commercial maritime communications	Marisat 1	02/19/76
Ocean resources satellite	SeaSat 1	06/27/78
Space Flight and Propulsion		
Multiple spacecraft payload	Transit/Solrad	06/22/60
Payload recovery	Discoverer 13	08/10/60
Hydrogen rocked orbited	Centaur 2	11/27/63
Docked spacecraft maneuver	Gemini 10-Agena	07/18/66
Lunar-velocity reentry	Apollo 4	11/09/67
Constant deceleration reentry	Apollo 8	12/21/68
Mars orbit	Mariner 9	05/30/71
Jupiter flyby	Pioneer 10	03/03/72
Solar system escape	Pioneer 10	03/03/72
Venus/Mercury flyby	Pioneer 10	03/03/72
Jupiter/Saturn flyby	Pioneer 11	04/05/73
Libration point halo orbit	ISEE 3	08/12/78
Auxiliary Power Systems		
Solar cells	Vanguard 1	03/17/58
Isotope power	Transit 4A	06/29/61
Nuclear reactor in orbit	Snapshot 1	04/03/65
Fuel cell	Gemini 5	08/21/65

TABLE 7. Major U.S. and Soviet Space "Firsts"--continued

Event	Satellite	Launch Date
Union of Soviet Socialist Republics		
Civil and Military Applications		
Domestic communications	Molniya 1-1	04/23/65
Fractional orbit bombardment	Kosmos 139	01/25/67
Co-orbital antisatellite test	Kosmos 248 & 249	10/20/68
Radar ocean surveillance	Kosmos 626?	12/29/73
Space Flight and Propulsion		
Space flight	Sputnik 1	10/04/57
Earth escape spacecraft	Luna 1	01/02/59
Lunar impact	Luna 2	09/12/59
Orbital platform launch	Sputnik 5	02/12/61
Venus flyby	Venera 1	01/12/61
Mars flyby	Mars 1	11/02/62
Venus impact	Venera 3	11/16/65
Lunar soft landing	Luna 9	01/31/66
Lunar orbiter	Luna 10	03/31/66
Automatic docking	Kosmos 186/188	10/27-29/67
Recovery, lunar payload	Zond 5	09/21/68
Skip reentry lunar payload	Zond 6	11/10/68
Venus soft landing	Venera 7	07/17/70
Mars impact	Mars 2	05/19/71
Mars soft landing	Mars 3	05/28/71
Venus orbit	Venera 9	06/18/75
Automatic propellant transfer	Progress 1	01/20/78
Auxiliary Power Systems		
Battery power	Sputnik 1	10/04/57
Gallium arsenide solar panel addition	Salyut 7	04/19/82

Prepared by CRS.

PART TWO

SPACE ACTIVITIES OF OTHER LAUNCHING COUNTRIES/ORGANIZATIONS

For the first two decades of the space program, the United States and Soviet Union clearly dominated space activities. While they still are responsible for the vast majority of space launches today, the 1980s
are witnessing the emergence of at least four additional launching countries/ organizations: China, the European Space Agency (a group of 13 European nations), India, and Japan.

Four other countries--Australia, France, Italy, and the United Kingdom-- are sometimes counted as launcher countries, but are not included here. Australia and Italy have both operated launch facilities, although the Australian site (Woomera) is now closed. In addition, Australia launched its own satellite, Wresat, from Woomera in 1967. Since a U.S. rocket was used for the launch and no other Australian launches have been made, it is not counted here as a launcher country. Italy's facility (the San Marco Platform off the coast of Kenya) is still used occasionally, and Italy has launched four of its own satellites, but these also have used U.S. launch vehicles, so Italy is not counted as a launching country.

France and the United Kingdom did develop their own launch vehicles. The French Diamant successfully placed 12 payloads in orbit from 1965 to 1975, but was then phased out of service. At first, the French launched from Hammaguir, Algeria. In 1970, they transferred operations to the Kourou facility in South America. The British Black Arrow successfully placed one satellite (Prospero) in orbit in 1971 from Woomera, Australia, but the rocket was never used again for space launches. Since their indigenous launch vehicles are no longer in use, neither country is included here as a separate launching country, although both are now members of the European Space Agency (ESA).

CHAPTER 1: CHINA

China launched its first satellite in 1970. By the end of 1986, it had made a total of 17 successful launches, successfully placing 18 satellites into orbit. Several of these have been recovered and are thought to be related to development of a reconnaissance satellite capability (recovery is necessary for film-type reconnaissance satellites). Several others were not recovered and their missions remain unclear. They could have had scientific missions or could have been related to a different type of reconnaissance capability (electronic intelligence, for example). One launch in 1981 which placed three spacecraft into orbit simultaneously was definitely for scientific purposes. Others have been for communications.

Most of the Chinese launches take place from Shuang Cheng-tzu in the northern part of China (near Jiuquan). In 1984, the Chinese introduced their new Long March 3 (CZ 3) launch vehicle, which has a cryogenic (liquid oxygen/liquid hydrogen) upper stage. China is only the third entity to use that type of high efficiency liquid fuel (after the United States and ESA). The vehicle inaugurated use of a new launch site at Xichang in southeastern China. The first launch of the CZ-3 did not put the payload in the correct orbit and is counted in this report as a launch success, but a payload failure. Two successful launches of the CZ-3 have followed and placed Chinese communications satellites in geostationary orbit. The Chinese are now actively marketing the CZ-3 (as well as the smaller CZ-2) abroad.

Several American companies have entered into discussions with the Chinese, and some have signed contracts with China to launch communications satellites in 1988. Pan Am Pacific Satellite and Western Union reportedly have launch contracts with the Chinese. Dominion Video Satellite Inc. has also been cited in the press as having such an agreement for launching a direct broadcast satellite in 1987. Determining the actual state of affairs with regard to Western companies launching on Chinese satellites is difficult since accounts in the trade press often vary. The U.S. company Teresat has stated for many months that it had an agreement with China to launch the refurbished Westar and Palapa satellites retrieved by a space shuttle crew in 1984. Teresat never owned the satellites, however, and the Westar satellite was later sold to Pan Am Pacific Satellite which will launch the satellite on a CZ-3 in 1988. Teresat now reportedly has teamed with Western Union and will jointly be involved in another Westar launch (Westar 6S) in 1988. In some cases, the problems seem to lie in over anxious promoters confusing "discussions" with "letters of intent" and actual launch contracts. China has stated that 17 foreign companies have contacted the Great Wall Industrial

Corporation, part of the Chinese Ministry of Astronautics, which is responsible for these launches.

The Chinese inaugurated use of a Landsat receiving station purchased from the United States in 1986. It may also be able to receive data from the French SPOT Earth resources satellite.

In 1984, China signed three agreements for cooperation in space technology with the Federal Republic of Germany, Italy, and France, and reported that discussions are underway with Brazil. With regard to the United States, the Chinese have indicated that they would like to fly an astronaut on the space shuttle, and in 1986 selected two student experiments for the shuttle once it resumes operations.

The Chinese announced in 1984 that they had flown a puppy into space on a suborbital rocket in 1967. The puppy, named Xiao Bao (Little Leopard), was successfully recovered. They also reported that there had been a major explosion at one of their launch pads on January 28, 1978, which resulted in at least seven people being seriously injured, and a dozen or more people receiving burns to their hair, eyebrows, and faces. In addition, they honored as a martyr a young engineer who helped develop the first geostationary satellite, but died after 6 or 7 years of suffering the health effects of exposure to radiation during experiments related to that task.

It is extremely difficult to discuss the future of the Chinese space program, not only because they do not release very much information about their activities, but also because their plans change quite abruptly. During 1979 and 1980, they expressed great plans for utilization of space, and even had astronauts in training. In late 1980 and early 1981, however, they retreated from their expansive plans because of a reassessment of the Chinese economic situation. Agreements to purchase broadcasting satellites from the United States were cancelled, and they announced that their manned space program had been postponed for at least the remainder of the decade. Today, they talk boldly about building space stations and a space shuttle, although it does not seem likely that they would do so before the year 2000.

TABLE 8. Chinese Space Launches

Name	Launch Date	Launch Site	Comments
China 1	04/24/70	SCt	Engineering test. "East is Red" song played until 05/20/70.
China 2	03/03/71	SCt	Housekeeping test and possible science.
China 3	07/26/75	SCt	Science? Reconnaissance? Not recovered.
China 4	11/26/75	SCt	Possible reconnaissance test. Recovered.
China 5	12/16/75	SCt	Like China 3.
China 6	08/30/76	SCt	Possible electronics intelligence gathering test and/or science. Not recovered.
China 7	12/07/76	SCt	Possible reconnaissance test. Recovered.
China 8	01/26/78	SCt	Possible reconnaissance test. Recovered.
China 9-11	09/19/81	SCt	Triple scientific payload for space physics experiments.
China 12	09/09/82	SCt	Possible reconnaissance test. Recovered.
China 13	08/19/83	SCt	Possible reconnaissance test. Recovered.
China 14	01/29/84	Xichang	Possible failure of new upper stage.
China 15	04/08/84	Xichang	First Chinese geostationary communications satellite.
China 16	09/12/84	SCt	Possible reconnaissance. Recovered.
China 17	10/20/85	SCt	Possible reconnaissance. Recovered.
China 18	02/01/86	Xichang	Communications.
China 19	10/06/86	SCt	Possible reconnaissance. Recovered.

SCt = Shuang Cheng-tzu. Launch dates are in Greenwich Mean Time.

Prepared by CRS based on data from Chinese news bulletins; World-Wide Space Activities (House Science and Technology Committee, 1977); and P. S. Clark, The Chinese Space Programme, Journal of the British Interplanetary Society, v. 37, p. 195-206, 1984.

CHAPTER 2: EUROPEAN SPACE AGENCY AND ARIANESPACE

The European Space Agency (ESA) was formed in 1975 by the merger of the European Scientific Research Organization and the European Launcher Development Organization. It has thirteen members (Austria, Belgium, Denmark, France, Federal Republic of Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom), and a technical agreement of cooperation with Canada as well.

A major ESA activity has been development of an independent launch capability using a launch vehicle called Ariane. France played the lead role in developing Ariane, and the vehicle is launched from Kourou in French Guiana (South America). In addition, Arianespace, a private company which now markets Ariane and manages the launches, is incorporated in France. As a result, Ariane is often mistakenly referred to as a French launch vehicle.

Arianespace, as noted above, is now responsible for Ariane launches so it, rather than ESA, is the "launching organization" included here. ESA continues to upgrade Ariane performance, so is still involved in the launch vehicle effort, and its activities will continue to be included in this report.

In light of the 1986 decision by President Reagan that the space shuttle may carry only shuttle-unique commercial payloads, Ariane is in a position of leadership in the West for conducting space launch operations. Ariane had its own problems in 1986, however. After two successful launches in 1986, it failed in May and has yet to resume service. Arianespace is expecting to resume launches in the spring of 1987. (Ariane is not the only way of putting a commercial payload in space. Several U.S. companies have been trying to market launches and in 1986 Martin Marietta signed a contract with Federal Express to launch a satellite. China, as already noted, is heavily involved in marketing and the Soviet Union has recently renewed its initiatives in this area.)

As noted above, ESA will continue to develop advanced versions of Ariane, and is currently discussing plans for the Ariane 5 which, in addition to being capable of placing 15,000 kilograms into low Earth orbit or 4,500 kilograms into geostationary orbit, would be reusable. According to the Europeans, this would make the system comparable to the U.S. space shuttle. France has proposed development of a small reusable manned vehicle called Hermes which could be launched on an Ariane 5, and ESA approved development of Hermes in 1986.

ESA's space activities encompass a broad range of science and applications satellites, and its programs have involved a considerable degree of cooperation with the United States. This cooperation has resulted in some discord, however, because of budget constraints within NASA which led to cancellation of the U.S. half of a joint project called the International Solar Polar Mission (ISPM). Originally, ISPM would have involved the launch of two probes to simultaneously study the North and South poles of the Sun. ESA and NASA would each have provided one spacecraft, and NASA would have supplied the power unit (a radioisotope thermal generator), launch, and tracking for both probes. In 1981, the United States unilaterally abrogated the memorandum of understanding with ESA on ISPM, prompting formal statements of displeasure from several ESA member countries to the U.S. State Department. Nevertheless, the mission could not be accommodated within NASA's budget, and the U.S. spacecraft was cancelled. NASA has kept its commitment to provide the power unit, launch, and tracking for the ESA spacecraft, which has been renamed Ulysses and was to have been launched in 1986. It is now in storage awaiting the resumption of shuttle flights and a favorable launch window (it can be launched only once every 13 months). As noted in earlier chapters, decisions on what planetary spacecraft will be launched when continues to be a matter of debate, although it seems most likely that Ulysses will be launched in the fall of 1990.

Relations between NASA and ESA have cooled slightly because of the ISPM incident, but the two agencies continue to develop programs jointly. For example, ESA has agreed to participate in NASA's space station program, building on its experience with Spacelab, a scientific laboratory which is carried inside the cargo bay of the space shuttle, thereby providing a "shirt-sleeve" environment for performing a wide variety of experiments.

Spacelab was developed as a cooperative project with NASA during the 1970s. Spacelab pallets have also been developed by ESA for use outside the habitable module for those experiments which require exposure to the space environment. The first Spacelab module was turned over to NASA in December 1981, and was launched in November 1983. The crew included an ESA astronaut, Ulf Merbold of West Germany, the first non-American to fly on an American manned mission. West Germany was the lead country in Spacelab development and, along with Italy, proposed using Spacelab modules to form a European space station. Called Columbus, the concept served as the basis for plans to provide a manned module as part of the NASA/international space station. The total cost for development, manufacture and utilization of Columbus modules and components is expected to be $2.1 billion over seven years. ESA is also developing a free-flying platform called Eureca (European Retrievable Carrier) as a follow-on to the Spacelab pallet. Eureca platforms will serve as a structure (or "bus") for providing power supply and orbit stabilization systems for payloads which can be placed on and later removed from it. The platform will be deployed from and retrieved by the U.S. space shuttle, and can accommodate 1000 kilograms of payload. The first payload will be five facilities for materials processing and life sciences experiments, and the Inter-Orbit Communications package for relaying data to the ground

through a planned European communications satellite operating at 30/20 gigahertz.

ESA launched a spacecraft called Giotto to Halley's Comet in 1985. The probe was the only one of the five Halley's Comet probes to enter the nucleus of the comet, and it returned excellent data that is still being analyzed. ESA's next scientific satellite is an Earth orbiting astronomical observatory called Hipparchos which will be launched when Ariane resumes service.

TABLE 9. European Space Agency/Arianespace Launches

Name	Launch Date	Comments
CAT	12/23/79	Success. First test launch. Carried CAT test package.
Firewheel; Oscar 9	05/23/80	Failure. Second test launch. One scientific and one communications satellite lost.
Meteosat; Apple	06/19/81	Success. Third test launch. Launched. European weather satellite and experimental Indian satellite.
Marecs	12/20/81	Success. Fourth and final test launch.
Marecs B; Sirio 2	09/09/82	Failure. First operational launch. Two communications satellites lost.
ECS; Oscar 10	06/16/83	Success. Placed two communications satellites in orbit.
Intelsat	10/19/83	Success. Communications satellite.
Intelsat	03/05/84	Success. Communications satellite.
GTE Spacenet	05/22/84	Success. Communications satellite. First launch operations by Arianespace.
ECS-2; Telecom 1A	08/04/84	Success. Two communications satellites.
GTE Spacenet; Marecs B2	11/9/84	Success. Two communications satellites.
Arabsat; Brazilsat	02/08/85	Success. Two communications satellites.
GSTAR-1; Telecom 1B	05/08/85	Success. Two communications satellites.
Giotto	07/02/85	Success. Halley's Comet probe.
GTE Spacenet; ECS 3	08/12/85	Failure. Two communications satellites lost.
SPOT; Viking	02/22/86	Success. French remote sensing satellite and Swedish scientific satellite.
GSTAR III; Brazilsat	03/28/86	Success. Two communications satellites.
Intelsat	05/30/86	Failure. One communications satellite lost.

* All launches are from Kourou, French Guiana (South America). Does not include launches conducted for Europe by other countries. Prepared by CRS based on information taken from Aviation Week and Space Technology, Flight International, Aerospace Daily and other trade publications.

CHAPTER 3: INDIA

India has been involved in developing satellites and launch vehicles for many years. Its first satellite, Aryabhata, was launched by the Soviet Union in 1975. While cooperation with the Soviets has continued (they launched two remote sensing satellites, Bhaskara 1 and 2, for the Indians in 1979 and 1981 respectively), India has also pursued development of an independent launching capability. The Indian Space Research Organization (ISRO) is the primary Government space agency in India, and is based in Bangalore. Launches are made from Sriharikota on the southeastern coast.

The first test launch of the Indian booster SLV-3 failed in August 1979. The Indians achieved success with their second test launch on July 18, 1980, however, which placed the Indian satellite Rohini 1 into Earth orbit (it remained in orbit until July 1981, longer than expected). The third SLV-3 flight took place on May 31, 1981, and although it succeeded in placing Rohini 2 into orbit, the altitude was lower than planned and the satellite decayed after only 9 days (instead of the expected 300 days). These Rohini satellites are primarily for monitoring the performance of the launch vehicle, although Rohini 2 also carried remote sensing equipment. On April 17, 1983, the Indians orbited Rohini 3 and announced it was for Earth resources studies. Some Western sources have suggested that the Indians are attempting to develop a military reconnaissance capability. No launches have been made by India since 1983.

Western press reports have indicated that India plans to spend $500 million on space activities between 1985 and 1990. The focus of the Indian space program is development of launch vehicles, and communications, remote sensing, and meteorological satellites.

The Indians developed a communications satellite, APPLE, which was launched on the third Ariane test flight in June 1981. One of the solar panels did not deploy properly, but the satellite operated with reduced power for two years. In April 1982, the United States launched INSAT 1A for the Indians. The satellite had three functions: meteorology, voice and data transmissions, and direct broadcast transmissions. Several problems developed with the satellite once it was in orbit (the solar sail did not deploy at all, and the C-band antenna would not deploy for several weeks), and by September its fuel supply (which should have lasted for many years) was exhausted, apparently because an open valve allowed the fuel to escape. The back-up satellite, INSAT 1B, was launched by the space shuttle in 1983 and is operating correctly. INSAT 1C was scheduled for a shuttle launch in 1986. The Indians are now seeking other launch arrangements.

In April 1984, an Indian military pilot, Rakesh Sharma, flew into space on Soyuz T-11 with two Soviet cosmonauts and docked with the Salyut 7 space station, which was already occupied by three other cosmonauts. Sharma remained on board the space station for seven days, participating in a variety of experiments including performing yoga to determine if special muscle relaxation techniques would help overcome the temporary physiological effects of weightlessness. The Indians also plan to send a scientist into space on a U.S. space shuttle mission.

TABLE 10. Indian Space Launches*

Name	Launch Date	Comments
SLV 3	08/10/79	Test flight. Failed.
Rohini 1	07/18/80	Test satellite. Success.
Rohini 2	05/31/81	Test satellite. Lower orbit than planned.
Rohini 3	04/17/83	Remote sensing. Success.

* Does not include launches conducted for India by other countries. Prepared by CRS from information appearing in trade publications such as Aviation Week and Space Technology and Aerospace Daily.

CHAPTER 4: JAPAN

Over the past several years, Japan has released space program plans for the future which involve a very ambitious level of activity, including the possibility of launching astronauts on the U.S. space shuttle and possibly developing its own manned program. To date, however, the Japanese space program has focused on development of launch vehicles, and communications, weather, and scientific satellites. There are two organizations involved in launching satellites in Japan: the National Space Development Agency (NASDA), and the Institute of Space and Astronomical Science (ISAS).

Japan uses a mixture of U.S. and Japanese technology in its space activities. Some Japanese satellites have been purchased from U.S. aerospace companies, while others were built by Japanese firms subcontracting with U.S. companies. During the early years of the program, some orbital launches were provided by the United States, but NASDA now relies on the "N" launch vehicle which is manufactured in Japan under license from the McDonnell-Douglas Corp. A smaller rocket, called the Mu, is the one used primarily by ISAS for scientific satellites. The ISAS launch facility is on the island of Uchinoura, 900 kilometers southwest of Tokyo. NASDA launches from Tanegashima, an island south of Uchinoura.

Like ESA, Japan is likely to offer stiff economic competition to the United States, but not in terms of providing launch services. Rather, Japan seems likely to compete in the area of space technology itself, particularly communications satellites and associated ground stations. For example, in 1977, the Japanese launched the first experimental communication satellite to operate at the frequencies of 30/20 Gigahertz. Most communication satellites today operate at lower frequencies, and those bands are becoming congested; 30/20 GHz technology is expected to be the wave of the future. In the United States, policy disputes over whether the Government or private industry should pay for developing advanced communication satellite technology such as this slowed development of U.S. technology, while the Japanese forged ahead. Their first operational 30/20 GHz satellite, CS 2, was launched in February 1983.

Development of communications satellites in Japan did not take place without difficulties, however. In 1979 and 1980, Japan lost two communications satellites (Ayame 1 and 2) after launch. The first satellite impacted the upper stage of its launch vehicle after separation, and the second was lost when the apogee kick motor used to place the satellite in geostationary orbit malfunctioned. In the latter case, the kick motor had been purchased from a U.S. company,

and the Japanese subsequently indicated that they would develop their own kick motors for the future.

In 1981, the Japanese successfully launched the first improved version of the "N" launch vehicle, "N II", which can place 350 kilograms in geostationary orbit. They also announced plans to develop an H-1 vehicle which can place 550 kilograms in geostationary orbit, and uses liquid hydrogen/liquid oxygen fuel. The first test launch of the H 1 was successfully conducted in 1986. The 1969 agreement with the United States which allows access to launch vehicle technology prohibits Japan from transferring that technology to third countries and from launching satellites for third countries without prior agreement from the United States. Because of this latter provision, Japan is not seen as a near-term launch competitor to the United States. Japan is planning to develop the H-2 launch vehicle, which will be more capable than the H-1 (two tons to geostationary orbit) and will be built entirely by Japan. This will relieve them of the restrictions placed on them by the 1969 agreement with the United States.

In the payload area, Japan has ambitious plans for the future as well. Japan is also planning to send a probe to the Moon which will first conduct orbital operations, and then deliberately crash into the lunar surface. Also planned is a Marine Observation Satellite for launch in 1987 to study ocean surface temperatures.

Other approved programs focus on developing more advanced communications, meteorological, and remote sensing satellites. In the latter category, the ERS satellite is scheduled for launch in 1990 (originally a 1986 launch date had been proposed) and will help explore for oil and mineral resources. Current plans call for the satellite to carry a synthetic aperture radar, a stereo camera, and visible and infrared radiation measurement systems.

Japan has also stated an interest in constructing a "mini-shuttle." Smaller than the U.S. space shuttle, the Japanese version would have most of the shuttle's basic features, including reusability, and could carry a crew of four. This proposal is in the very early stages of discussion and has not been approved. The Japanese have selected three astronauts to fly with Japanese payloads on the U.S. space shuttle.

Japan is participating with NASA in the development of the space station, and has chosen Mitsubishi Heavy Industries as prime contractor for building a pressurized module which will be affixed to the U.S. space station. Japan has agreed to spend $1 billion over 10 years in support of the space station program.

In 1981 the Japanese raised the possibility of launching military reconnaissance satellites and using communications satellites to support their Self Defense Forces. The 1969 space cooperation agreement with the United States requires Japan to use U.S.-derived space technology only for peaceful purposes, and a 1969 resolution passed by the Diet also states that Japan will engage only in "peaceful" space activities. There is a continuing debate over

whether reconnaissance and communications satellites would be counted as "peaceful" even though they are used by the military, since they are non-aggressive. In 1983, the Japanese Government approved plans for the military to use the CS2 communications satellite, but internal debate in Japan continues.

TABLE 11. Japanese Space Launches*

Name	Launch Date	Launch Site	Comments
Osumi Lambda 4S-5	02/11/70	U	Test flight.
Tansei MS-T1	02/16/71	U	Test flight.
Shinsei SS-1	09/28/71	U	Science.
Denpa REX SS-2	08/19/72	U	Successful launch; payload failed.
Tansei 2 MS-T2	02/16/74	U	Test flight.
Taiyo SRATS	02/24/75	U	Science.
Kiku ETS 1	09/09/75	T	Test of new N launch vehicle.
Ume ISS	02/29/76	T	Launch success, payload failure (for science).
Tansei 3 MS-T3	02/19/77	U	Engineering test.
Kiku ETS 2	02/23/77	T	First Japanese launch to geostationary orbit; test satellite.
Kyokko (Exos A)	02/04/78	U	Science.
Ume 2	02/16/78	T	Ionospheric sounding.
Jikiken (Exos B)	09/16/78	U	Science.
Ayame 1 (ECS-1)	02/06/79	T	Failed to reach geostationary orbit.
Hakucho (Ccrsa B)	02/21/79	U	Science.
Tansei IV	02/17/80	U	Test satellite.
Ayame 2 (ECS-2)	02/22/80	T	Failed to reach geostationary orbit.
Kiku-3 (ETS-4)	02/11/81	T	Engineering test.
Hinotori (Astro A)	02/21/81	U	Science.
Himawari 2	08/10/81	T	Weather.
Kiku-4	09/03/82	T	Engineering test.
Sakura (CS-2A)	02/004/83	T	30/20 GHz communications.
Hinotori (Astro B)	02/20/83	U	Science.
Sakura (CS-2B)	08/05/83	T	30/20 GHz communications.
Yuri 2A	01/23/84	T	Operational 30/20 GHz communications.
EXOS C	02/14/84	U	Science.
Himawari 3	08/03/84	T	Weather.
Sakigake (MSTS)	01/08/85	U	Halley's Comet probe.
Suisei (Planet A)	08/18/85	U	Halley's Comet probe.
BS2B	02/12/86	T	Communications.
Ajisai; Fuji	08/18/86	T	Test of new H 1 rocket. Ajisai is geodetic satellite; Fuji is for amateur radio.

* Does not include launches of Japanese satellites by other countries. For launch failures prior to 1977, see World Wide Space Activities (House Science and Technology Committee, 1977), p. 203. Prepared by CRS from information in that publication, plus Japanese press announcements, and U.S. trade publications such as Aviation Week and Space Technology and Aerospace Daily.

Launch dates are in Greenwich Mean Time. U = Uchinoura; T = Tanegashima.